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United States
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Forest Service

Rocky Mountain
Forest and Range
Experiment Station

Fort Collins,
Colorado 80526

December, 1986

Protocols for Establishing Current Physical, Chemical, and Biological Conditions of Remote Alpine and Subalpine Ecosystems

PUBLIC REVIEW DRAFT

This draft document is for public review only. The protocols described, when adopted, are intended for use by any interested federal land managers, particularly those involved in Prevention of Significant Deterioration (PSD) permitting. (40 CFR 51.24) Written comments will be accepted until February 6, 1987. They should be submitted to Dr. D. G. Fox, Rocky Mountain Forest and Range Experiment Station, 240 W. Prospect Road, Fort Collins, CO 80526.

USDA FOREST SERVICE
ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Protocols for Establishing Current Physical, Chemical, and Biological Conditions of Remote Alpine and Subalpine Ecosystems

PUBLIC REVIEW DRAFT

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December, 1986

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REVIEW COMMENT GUIDELINES

Reviewers are encouraged to submit comments on the technical quality and accuracy of the material presented in this document. Both general and specific comments will be useful. Please make your comments specific and indicate the section and page numbers of the discussion in question. This will greatly increase the likelihood that the Work Groups will be able to address your comments adequately. We hope your comments will also specify strengths as well as any weaknesses in the protocols that you may find.

During your review of this document, please keep in mind the intended purpose and scope of this document as described in the introduction. This document is designed to provide the technical information needed by Federal land managers to develop handbooks and guidelines for establishing baseline conditions in alpine and subalpine wilderness areas. This document is not designed to address policy option issues. The Work Groups are charged with producing scientifically sound and accurate protocols and are not expected to make recommendations for the use of these protocols in future decision-making processes. The Work Groups will therefore address comments only on technical aspects of the protocols.

The deadline for written comments is February 6, 1987.

Please send comments to Dr. Douglas G. Fox, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 240 W. Prospect Street, Fort Collins, CO 80526.

DOCUMENT REVIEW FORM

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Reviewer/Organization/Address/Phone No.

Summary Recommendation:

___ (1) Acceptable as is
___ (2) Acceptable after minor revision
___ (3) Acceptable after major revision
___ (4) Not Acceptable

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INTRODUCTION

Background

This document is the Public Review Draft of a report to the U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station. The purpose of the report is to provide the necessary technical information to support, and from which Federal land managers can develop, land management Handbooks and Manuals. The report presents appropriate scientific protocols to measure current conditions of air quality related values (AQRV's) in alpine and subalpine wilderness areas. These protocols are intended for quantifying the existing status of AQRV's, monitoring for changes from these existing conditions, and subsequently, evaluating whether the changes are naturally occurring or the result of man-caused air pollution/chemical deposition. Certain regulatory and management requirements have constrained the development of the protocols presented in this report. These constraints are explained fully in the first section.

The scientists and contributors developing this document have been divided into six work groups with the Work Group Leaders responsible for the development of protocols for the five technical areas: 1) Atmospheric Environment, 2) Soils and Geology, 3) Aquatic Chemistry and Biology, 4) Vegetation, and 5) Regulatory and Management Constraints. A sixth group, Government Applications, was added shortly after the project began.

A meeting was held in Fort Collins, CO in late January 1986 to bring the researchers developing the protocols together with some of the Federal land managers and regulators who will be the users of the products of this project. Discussions of draft lists of measures resulted in productive interaction between the researchers and regulators, and the exchange of information and perspectives resulted in substantial progress towards consensus. Shortly after this meeting and after further internal review of the lists, the Work Groups began to prepare their draft protocols.

A second meeting, The Protocol Refinement Workshop, was held in June 1986 to 1) provide an opportunity for the project team to refine the draft protocols; 2) widen the sphere of participation in reviewing and refining protocols by involving some key external users and scientists; and 3) aid in a smooth transition to the larger consensus development meeting, i.e., the Public Review. Consensus building among diverse stakeholders and other interested parties is an important component of this project; Involving key industry, state, federal, and environmental groups prior to the public review meeting allowed productive interaction and enabled the Work Group Leaders to address some emerging technical concerns early in the process.

The final task of this phase of the project is the Public Review Meeting in December 1986. The purpose of this meeting is 1) to educate the participants on Federal Land Managers' needs and regulatory and management constraints, and 2) to allow review and discussion on key <u>technical</u> issues and to develop consensus on these issues.

<u>Protocol Development</u>

Several basic project assumptions were discussed and clarified at the June meeting to provide guidance in the preparation of these wilderness protocols:

1. The protocols being developed are for high-elevation western areas.

2. The measurements and protocols will be used by Federal land managers and air quality permitting authorities specifically for the protection of "air quality related values" of national wilderness areas designated as class I areas under the Clean Air Act.

3. The measurements are <u>not</u> part of a research project but will be conducted to fill specific resource management regulatory information needs.

4. In most cases, the land manager's/permitting authority's needs will be met by the measurement of change in the most sensitive component of the ecosystem. The determination of whether a change is adverse is the responsibility of the Federal land manager.

All possible attributes cannot be measured and the list must be parsimonious and practical. Several filters must be used for an attribute to be included in the list. An attribute should have ecological significance and should be likely subject to change as a consequence of air quality effects. Ideally, it should change only in response to changes in air quality and nothing else; clearly an impossibility! The attribute measured and the method of measurement must be defensible to a consensus of the scientific community. Non-destructive methods are preferable not only because of wilderness regulations but also because repeated measurements of the same organism or assemblage is advantageous. Attribute variables which can be monitored with low frequency should be given consideration over those which require many measurements at intervals of less than one year. Only those attributes which can be readily measured with high accuracy should be considered.

Problem

There are several important reasons for systematically establishing protocols for methods and techniques for monitoring current AQRV conditions and tracking future condition changes. These reasons include the following:

- to provide clarity internally for the Forest Service in wilderness management, planning, operations and decisions and externally to states and prospective new air pollution sources about what the Federal Land Manager (FLM) considers necessary in monitoring baseline AQRV conditions and potential air pollution-caused changes in those baseline conditions;

- to reduce the period of time needed to conduct complete AQRV impact analyses during the air quality permit review process;

- to provide a standardized approach to AQRV impact analysis so that different parties' analyses and findings can be compared and so that analyses in different permitting cases can be compared with one another;

- to provide a framework for due process with respect to both the Forest Service's AQRV impact analyses and findings and its broader wilderness protection mandate, thus enhancing the defensibility of such analyses and findings in regulatory and judicial proceedings; and

- to the extent feasible, to reduce to a minimum the conflict and controversy over technical issues surrounding AQRV sampling, monitoring and measurement, thus limiting disagreement where possible to value judgments about whether a projected AQRV effect is considered an "adverse impact."

In science, in administrative regulation, and in politics, a universally employed approach to reducing conflict and controversy and increasing agreement and certainty is that of developing consensus positions on important issues. This consensus building approach is most appropriate for use in establishing AQRV monitoring protocols. The endeavor is a scientific one in a field where there are limited data and knowledge, i.e., air pollution effects on natural ecosystems. Thus, there is much room for competing scientific views and interpretations and much to be gained by seeking systematically to narrow differences of scientific opinion and to develop consensus. Moreover, the monitoring protocols and the data that result from their use are to be employed in regulatory proceedings concerning the permitting of new major sources of pollution. The regulatory decisions, which in part will be based on the monitoring data gathered, frequently will have the potential for sparking considerable political controversy,

regardless of whether the decision is to grant or to deny the permit. Development and use of scientific methods of monitoring and measurement which are broadly supported in the scientific community could generate regulatory decisions which would be more widely accepted.

The consensus building component of this project is the most difficult activity. Where there is little information and knowledge, such as in the case of air pollution effects on wilderness resources, scientific opinions can be expected to diverge widely. Moreover, the management, regulatory and physical constraints on conducting science in wilderness areas will contribute to the diversity of scientific opinion about the adequacy, representativeness, and significance of the limited data that can be gathered.

The Need for Protocols

Protocols for determining baseline conditions in high elevation ecosystems have several purposes. Federal land managers and regulators need implementable measures to determine if significant changes are occurring to wilderness areas in order to comply with the law and effectively steward these resources. Air quality decisions must be made now; they cannot await full scientific understanding or development of ideal measurement and monitoring techniques. Baseline information also will be valuable in fulfilling FLM's broader stewardship functions for these fragile alpine areas.

Protocols are essential to the FLM's air quality and management missions as well as to the process of sound scientific research. Standardized methods are crucial so that comparable data are produced from different studies and sites. Protocols help ensure reproducible results and document the procedures used so that future efforts can be related to old data. Uniformity of technique also is critical for appropriately extrapolating results. Scientifically credible protocols provide the needed basis for making sound regulatory, legal, and management decisions.

General Issues

Protocols of several types are needed. First, however, it must be established what should be measured to gauge man's impacts on high elevation ecosystems. Techniques and sampling and analytic procedures then must be determined that are appropriate to the physical, regulatory, and management constraints of wilderness areas. These constraints include rugged, remote, high altitude settings subject to extreme physical conditions; Wilderness Act statutory and related regulatory prohibitions; Clean Air Act requirements for permitting; and management constraints such as budget limitations.

Sampling frequency and location are key variables that must be determined given the degree of natural variability and physical limits on practical measurements. Not only in-depth knowledge of the natural systems, but also statistical design considerations bear on this issue. Technical approaches must be developed for the most practical and representative ways to make the required measurements in wilderness areas. Protocols are needed for both on-site and laboratory analysis so that sources of error can be minimized. A major challenge is designing sampling schemes that can adequately represent the diverse physical, chemical and biological variables.

Protocols also are needed for data reduction, analysis, and archiving. These post-measurement treatments of data and samples are an important consideration for developing results that will still be useful in the distant future. A quality assurance plan should be developed along with the other protocols to ensure reliable and meaningful results. Quality assurance/quality control is essential to characterize adequately the sources of error and the inherent uncertainties in the data collected.

Major concerns are how to address the inevitable tradeoffs between what measurements ideally are desirable scientifically and what is actually possible under the physical and legal constraints imposed by high elevation wilderness sites and limited resources for accomplishing the task. It could be argued that not enough is known even to determine what to measure, when or how. This approach is not a luxury that FLM's can indulge. The task at hand is the art of the possible; the immediate goal is to determine the best possible approach, fully document it and then proceed to use it knowing it is not ideal.

The protocols presented within this document are not intended to represent all that can be measured within wilderness ecosystems. Conversely, all of the measurements suggested here may not be necessary for a given site or situation. These protocols are presented as a reasonable list of measurements for establishing current conditions in alpine and subalpine areas to aid in detecting changes in the future. In addition, a mechanism must be provided for the integration of data collected on aquatic chemistry and biota, catchment soils, vegetation, and atmosphere. This integration will be critical to maximize confirming evidence for measured effects.

The high degree of scientific uncertainty about how atmospheric chemicals influence alpine ecosystems means on many issues no single widely accepted view exists. Consensus building must be part of the entire process so that the greatest degree of scientific credibility possible can be achieved. Part of the purpose of this project is to educate the research and technical community on what FLM's needs are, the reasons the FLM cannot wait for ideal approaches to be developed, and the legal and management constraints under which the FLM must act. The best current scientific judgment must be made, discussed, and agreed on to accomplish our goals.

Organization of Document

The first section of this document presents the paper prepared by Work Group 5, Regulatory and Management Constraints. The following sections present each set of protocols developed by Work Groups 1 through 4. The members of the Work Groups, including those in Work Group 6, Regulatory Applications, are listed on the page preceding the Table of Contents.

SECTION I

REGULATORY AND MANAGEMENT CONSTRAINTS PAPER

WORK GROUP 5
REGULATORY AND MANAGEMENT CONSTRAINTS

I. Introduction

This chapter briefly explains constraints on development and application of scientific protocols for the measurement and analysis of "air quality related values" (AQRVs) in alpine and subalpine wilderness areas. These constraints are imposed by the Clean Air Act (CAA) and the Wilderness Act (WA), the physical location of alpine and subalpine areas, weather, altitude, and other such factors. The draft protocols included in this document have been shaped and limited in their approach by the constraints identified here. Therefore, this chapter is intended to assist draft protocol reviewers in developing a full understanding and appreciation of the possible constraints on the development and implementation of the protocols.

II. Clean Air Act Context

The Clean Air Act Amendments of 1977 included a program for prevention of significant deterioration of air quality, generally referred to as the "PSD" program. In part, this PSD program was intended to safeguard the air quality-related values (AQRVs) of wilderness areas and national parks which the statute designates as "class I areas." This "class I" designation allows only very small "increments" of new pollution above the "baseline conditions"[1] within the area and subjects each such area's[2] AQRVs to special protection considerations under the Clean Air Act.

Under the CAA, the appropriate Federal Land Manager (FLM) is charged with an "affirmative responsibility" to protect the AQRVs of these class I areas from adverse air pollution impacts. In the case of the Forest Service, the Federal Land Manager's affirmative responsibility to protect AQRVs has been delegated to the Regional Forester for each National Forest in which a class I area is located.

The FLM's "affirmative responsibility" is implemented, in part, through the PSD new source review process, a preconstruction review and permitting program for major new or

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[1]"Baseline condition," as used in this document, means the scientifically monitored status of a resource at the time of the monitoring. This definition differs from the Clean Air Act definition of "baseline" that refers to air quality conditions at the time of the first completed PSD application for that area.

[2]There presently are a total of 158 class I areas, including the 88 National Forest wilderness areas, 49 National Parks which exceed 6,000 acres, and 21 National Wildlife Refuges that are wilderness.

expanding sources of pollution. Any major facility seeking a new source permit for location or expansion in a clean air area must meet several requirements, among them the class I and/or II increments, the so-called Air Quality Related Values "adverse impact test," and the Best Available Control Technology (BACT) evaluation. In the PSD permitting process, the FLM determines whether a proposed source's emissions will cause an adverse impact to class I AQRVs.

New source permit applicants submit plans to the permitting authority, who examines the proposed location of the facility, its general design, projected air pollution emissions, and potential impacts. When a proposed source's emissions may have an impact on a class I area, the permitting authority (EPA, or the state, if EPA has delegated PSD authority to that state) alerts the Federal Land Manager. The FLM then conducts an "adverse impact determination" to assess the impact the projected pollution level increases would have on the class I area. The application review process may take as little as thirty days or, with complex or controversial projects, possibly longer than one year. The FLM's adverse impact determination must be completed within this period.

III. Wilderness Act Context

A. Legal Direction for Managing Wilderness

The Wilderness Act describes the basic purpose of wilderness, defines the wilderness resource and character, and establishes management direction to preserve an enduring resource of wilderness. The Act's direction is the foundation for the implementing regulations, found in 36 CFR 293, 36 CFR 291, and Forest Service policy in FSM 2320.

Congress established the National Wilderness Preservation System in 1964 "to secure for the American people an enduring resource of wilderness." [Section 2(a) of the Wilderness Act]. The basic purpose of wilderness is "to assure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy and modify all areas within the United States. . . ." [Section 2(a)]

Congress has clearly defined the wilderness resource: "as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain, . . .an area of undeveloped Federal land retaining its primeval character and influence. . .which is protected and managed so as to preserve its natural conditions. . .generally appears to have been affected primarily by the forces of nature, . . .has outstanding opportunities for solitude or a primitive and unconfined type of recreation, . . . may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value." [Section 2(c)]

The Wilderness Act gives direction for the management of such areas, which "shall be administered for the use and enjoyment of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness, and to provide for the protection of these areas, [and] the preservation of <u>their wilderness character</u>. . . ." [Section 2(a)--emphasis added]. The preservation of wilderness character means striving to preserve "untrammeled" natural conditions and "outstanding opportunities for solitude." This meaning applies particularly to all wilderness management activities, including resource monitoring of all kinds. To clarify management direction, the Act spells out specific prohibitions, while allowing only <u>minimum</u> necessary exceptions for administration of the areas as wilderness:

> Except as specifically provided for in this Act, and subject to existing private rights, there shall be no commercial enterprise and no permanent road within any wilderness area designated by this Act and, except as necessary to meet minimum requirements for the administration of the area for the purpose of this Act (including measures required in emergencies involving the health and safety of persons within the area), there shall be no temporary road, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no other form of mechanical transport, and no structure or installation within any such area. [Section 4(c)]

The key to interpretation of this section of the Act is understanding that it was written to allow wilderness managers to use this exception only when "<u>necessary to meet minimum requirements</u>. . ." for managing the wilderness resource. Forest Service Wilderness Managers <u>and their agents</u> must be the leaders in demonstrating that wilderness management tasks (including monitoring of air pollution impacts on resources), can be done without structures, installations, or the use of motorized equipment.

The Forest Service must demonstrate that it is using the "minimum tool" necessary and is performing its management tasks in a manner compatible with the wilderness environment. The exception is to be granted only when it is clearly shown there is no other feasible way to gather information. This "minimum tool" principle must be the guiding premise for developing protocols for measuring physical, chemical, and biological baselines.

B. <u>Guiding Principles for Measurement Protocols in Wildernesses</u>

A specific set of principles must be applied by the land managers and regulatory agencies when establishing or applying measurement protocols for assessing baseline air quality related values in a wilderness.

1. FSM 2320 establishes wilderness management objectives and policy. Measurement protocols must be developed within these policies.

2. All components of the wilderness resource are equally important. The components are bio-physical or social. The bio-physical is based on the concept of natural processes dominating in wilderness. The social is based upon outstanding opportunities for solitude.

3. Each wilderness user must be highly sensitive to the potential impact of his or her activities on the bio-physical components of the wilderness resource and on the expectations and experiences of other wilderness visitors. Freedom from structures and mechanical equipment is a requirement of the law and one of the components of the wilderness resource.

4. The use of non-motorized and non-mechanical means of transportation is required for travel within a wilderness.

5. The minimizing of the effects of human use or influences on the natural ecological processes is the most important principle of wilderness management.

C. <u>Criteria for Considering Exemptions to the Prohibition of Structures, Installations, and Motorized Equipment in Wilderness</u>

Based on the current regulations and past Forest Service decisions under those regulations, measurement protocols which will require exemptions to the prohibitions against structures, installations, and motorized equipment in wilderness areas are unlikely to be considered favorably by the Forest Service. The criteria for considering exemptions are found in the Forest Service Manual in the following sections:

- Structures - 2324.3. This section sets criteria which are intended to limit structures to "those actually needed for management, protection, and use of the wilderness for the purposes for which the wilderness was established." This section also requires documentation of need for structures, schedules for their removal, and sets specific standards for materials and siting.

- Research - 2324.4. While "encouraging research in wilderness that preserves the wilderness character of the area," this section requires that research proposals be reviewed "to ensure that research areas outside the wilderness could not provide similar

research opportunities" and "to ensure that research methods are compatible with wilderness values." Further, it requires specific use stipulations in the approval document.

- o Motorized Equipment and Mechanical Transport - 2326 (all), specifically 2326.1 (item 5). In an effort to "exclude the sight, sound, and other tangible evidence of motorized equipment or mechanical transport within wilderness," this section lists the specific criteria for exemption from prohibitions on the use of motorized equipment and mechanical transport in wilderness.

In addition to the above, the Forest Service likely will give consideration to the following:

1. Is an exemption to use restrictions necessary to measure the impacts on a specific wilderness component within the wilderness? Proposals should include estimates of the applicability to wilderness of data gathered outside wilderness.

2. Are the data to be gathered under the proposed exemption necessary (or essential) for the protection of the wilderness resource?

However, it must be noted that in reviewing requests for exemptions to wilderness access/use restrictions, economic costs to, or the convenience of, the researchers are not to be considered.

In all likelihood, then, a request for an exemption is likely to be refused unless it can be demonstrated unequivocally that the data to be gathered under the exemption are absolutely necessary, and all possible alternatives to the exemption have been considered, and the data cannot be gathered in any other way.

D. <u>Guidelines and Constraints Used in Protocol Development</u>

Reviewers should evaluate the measures and protocols developed by the work groups in the context of the following guidelines and constraints.

1. Has the full protection of the wilderness resource been taken into account and are the protocols compatible with protecting the wilderness character?

2. Have the physical and environmental factors of wilderness adequately been taken into account in the development of the protocols?

3. Has the selection of specific "sensitive resources" been justified?

4. Have Forest Service/permitting authority resource limitations (dollars, time, personnel) been taken into account?

5. Are the AQRV monitoring and assessment techniques simple and quick to perform, document, report, and replicate?

6. Are the results of AQRV monitoring and assessment reliable?

7. Have the ranges of uncertainty in use of protocol been explicitly defined and fully explained?

8. Requests for exemptions will be handled only on a case-by-case basis and, as discussed above, will not be favorably considered unless no alternative approach is available for acquiring essential data. Exemption requests will be reviewed using the criteria found in FSM 2320 or described in this paper.

In conclusion, the Wilderness Act and the Forest Service regulations require the use of scientific protocols and measurements that protect wilderness values. This means that the measurements either must be easily obtainable within the wilderness by primitive means, or be obtained from representative sites outside the wilderness.

IV. Some Specific Constraints Taken into Account in Protocol Development

The following are examples of specific factors and issues which have constrained and shaped the draft protocol development. These examples are not intended to be exhaustive; rather they are offered as a means of informing the reviewer of the draft protocols of the types of considerations shaping the protocols.

- No guidance is given in the CAA as to how much advance notice the FLM must be given by the permitting authority to allow proper assessment of potential AQRV impacts of a proposed new source of air pollution. Although the FLM may have more than a year, in practice he may have as little as 30 days for conducting this analysis. Due to these time constraints, the FLM will not be free to begin a monitoring study after he is presented with the permit application. T be useful in the permitting process, data must have already been collected under the protocols. Moreover, the data must have been gathered over a sufficient time period to establish a meaningful baseline for the resource in question.

- The types of AQRV measurement and analysis that can be performed may be seriously constrained by certain physical and environmental factors in the alpine and subalpine setting. These factors include:

  - extreme rain, snow, ice, temperature, and wind conditions;
  - high elevation and subsequent low atmospheric pressure and lack of oxygen;
  - seasonality;
  - animal chewing and damage to equipment (in Sequoia National Park, marmots have chewed up plastic air sampling equipment and bears have damaged equipment within reach);
  - remoteness and size of wildernesses, particularly in the West, and subsequent access problems; and
  - little or no electrical power available (e.g., outside electrical power is unavailable and photovoltaic cells may not provide enough power for volumetric air sampling).

- Both the FLM and permitting authority routinely are subject to resource limitations (both dollars and personnel) which hamper their work efforts. The scientific procedures that can be conducted in the AQRV analysis likely will be constrained by a lack of skilled personnel and funding. [Experience suggests that for monitoring and measurement activities, undertaken in their entirety by the Forest Service, a maximum of perhaps $100,000 per year could be expended on developing data on AQRVs for a wilderness for which a major new source permit application actually is pending. For routine AQRV monitoring (not related to a pending or expected new source permit application), it would be reasonable to anticipate no more than approximately 20-50% of a person-year's time for field data collection and perhaps $10,000-20,000 for other expenses. These amounts are thought to be levels a Forest Supervisor might consider reasonable in a request for funding.] Thus, in general protocols should call for monitoring efforts that are simple and cheap, use current state-of-the-art methods and equipment, and do not push the boundaries of technology.

- Given constraints of time and lack of resources and personnel, a premium will be placed on AQRV analysis techniques that are simple and quick to perform, report, and replicate.

- Given the fact that the results of AQRV analysis are to be used in the new source permitting process (and, potentially, in subsequent judicial review) a premium will be placed on the reliability of the results and the subsequent ability to make and defend "yes" or "no" decisions concerning whether a proposed source will cause an adverse impact.

- o The Wilderness Act and Forest Service regulations pursuant to the Act under most circumstances prohibit the use of motorized vehicles (e.g., automobiles, helicopters, airplanes, or boats); the use of mechanical or motorized equipment; supply drops from aircraft; the erection of structures; the cutting of trees or removal of vegetation; site manipulation; and certain other activities in wilderness areas. [36 CFR 293.6] Such restrictions could be a particular hindrance to research efforts in alpine and subalpine zones. Thus, where an access/use restriction exemption is thought necessary, the protocols must provide sufficient justification for the exemption.

- o The ranges of uncertainty in determining potentially measurable changes in AQRVs (or in determining the significance of any given change) as the result of proposed source emissions should be clearly identified and described. The implications of such uncertainty should be described adequately for nontechnical decision makers in reporting the results of the AQRV impact assessment.

V. Conclusion

The constraints of the Clean Air Act, the Wilderness Act, management considerations, and the physical and environmental factors seriously limit the types of AQRV measurement and analysis that may be performed in alpine and subalpine wildernesses. Protocols were developed within these constraints to insure realistic and feasible techniques. Some compromises have been necessary between "ideal" or "preferred" AQRV measurement and analysis techniques and those which are deemed "adequate" for management and regulatory purposes. Therefore, the proposed protocols and associated AQRV research likely will be less than "state-of-the-art." Nonetheless, these protocols and techniques are intended to be scientifically sound and accurate enough for reliable determinations of AQRV baselines.

SECTION II

WORK GROUP PROTOCOLS

WORK GROUP 1
ATMOSPHERIC ENVIRONMENT

1.1 Purpose

A major objective of this atmospheric protocol is to determine an aerometric baseline for assessing the impact of airborne pollution-related material on sensitive ecosystems. To meet this objective, this protocol includes measurements for the ambient concentration of certain gases and aerosols, and for the concentration of pollution-related ions in cloudwater, precipitation, and snow pack. Dry and wet deposition of pollution-related material can be inferred from these ambient measurements.

Dry deposition fluxes can be computed by multiplying the ambient concentration of the pollutant above a surface by its deposition velocity, which is assumed to vary with land surface type, time of day, season, and several other factors. Meteorological measurements will therefore accompany the ambient concentration measurements. This approach represents a highly empirical parameterization relying heavily on a relatively sparse data base of dry deposition measurements.

Wet deposition can be estimated by multiplying the precipitation-weighted ion concentration by the total amount of precipitation, the latter measured by standard meteorological means. During the cold season, both wet and dry deposition are estimated directly from snow pack measurements.

Because of the difficulties of making aerometric measurements within the wilderness area, a representative site or sites will be established at the boundary of the wilderness area, where the inflow and outflow of pollution-related material can be monitored. Passive monitoring techniques such as measuring the total amount of precipitation, measuring the total snow pack depth, retrieving representative snow pack samples for laboratory analysis, and establishing a detailed inventory of land surface type can be accomplished within the wilderness area. These efforts are essential for estimating dry and wet deposition in the sensitive wilderness ecosystems.

This protocol will provide estimates of airborne pollution material to the land manager. Compliance with criteria pollutant regulations or with allowable air quality increments under prevention of significant deterioration (PSD) regulations is not being examined. Neither does this protocol establish air quality baselines for permitting new sources under the Clean Air Act.

This protocol makes maximum use of existing procedures and methodologies that have been, or are being, field tested as part of a national network. These include NADP/NTN, MAP3S, UAPSP, EPA'S Mountain Cloud Chemistry Project (MCCP), and the dry deposition networks proposed by EPA (as part of NTN) and EPRI (OEN).

Several critical assumptions have been made during the development of the atmospheric component of the protocol. These include:

1. Procedures and measurement methodologies to evaluate compliance with existing standards for criteria pollutants are not discussed. The concentrations for gases and particles within a wilderness area are expected to be well within existing standards. A notable exception may be ozone; its continuous measurement is therefore recommended at all sites as required for compliance testing.

   Should the need evolve for compliance testing based on preliminary assessments, taking into account results from model calculations and other efforts, then the methodologies published in the Federal Register will serve as protocols.

2. Models can be used for guidance in selecting regionally representative sites in this protocol, although these models may not be acceptable to the regulatory community for a variety of reasons.

3. The meteorological and aerometric measurements should be expanded spatially and temporally if the representativeness of the protocol measurements is in doubt. Aircraft sampling over the wilderness area and vertical profiles for meteorological data are powerful tools for documenting regional air quality, but they also are very cost intensive. If such measurements are necessary, several groups are available to operate research aircraft according to well-tested protocols.

1.2 <u>List of Measures</u>

1.2.1 <u>Warm Season</u>

1.2.1.1 <u>Gases and aerosols</u> - Table 1-1 summarizes the aerometric parameters that are measured in this protocol. Our knowledge of trace gas and aerosol exchange between the atmosphere and the earth's surface is limited to a small number of gases (mainly ozone, NO_2, HNO_3, SO_2, and NH3). In this protocol, dry deposition is calculated from measured ambient air concentrations. Actual deposition is inferred from concentration data and deposition velocities that have been determined for specific gases and surfaces. The following trace materials are measurement candidates:

<u>Sulfur dioxide</u> (SO_2) is a key primary pollutant of concern in the wilderness area. Dry deposition of SO_2, especially to moist surfaces, is considered a major sink, perhaps the major sink of this species. Uptake of SO_2 by vegetation and ecosystems is an acid-producing process.

Table 1-1.

Aerometric Measurements

Analyte	Measurement Method	Time Resolution	Quant. Detection Limit	Desired Accuracy
O_3	uv photometry, automatic	hourly	5 ppb	Lgr of QDL or 10%
NO_2	filter pack (TEA-impregnated filter following Teflon and nylon)	day/night* (12 hr each) for up to 1 wk average	0.1 ppb	Lgr of QDL or 20%
Mass, SO_4	filter pack (Teflon)	"	0.2 ppb	Lgr of QDL or 20%
Inorganic nitrate	filter pack (Teflon, nylon)	"	0.2 ppb	Lgr of QDL or 20%
Total ammonia	filter pack (oxalic acid-impregnated filter following Teflon)	"	0.2 ppb	Lgr of QDL or 20%
SO_2	filter pack (KOH-impregnated filter following Teflon)	"	0.2 ppb	Lgr of QDL or 20%

*With the option to measure over a 24-hr period only.

Nitrogen dioxide (NO_2) is the second species of direct concern in the wilderness area. This gas is relatively insoluble in water and is highly reactive to substances present in the environment, e.g., biological materials. Chamber studies as well as field measurements indicate that NO_2 can dry deposit at moderate rates.

Ozone (O_3) is formed in the atmosphere as a product of reactions involving hydrocarbons and nitrogen oxides. This connection with nitrogen oxides alone establishes its importance to the wilderness area. Ozone also is a major source of free radicals that drive not only gas-phase oxidation of NO_2 (to HNO_3), and SO_2 (to H_2SO_4) but also form hydrogen peroxide (H_2O_2), and other peroxides that are responsible for aqueous-phase oxidation of SO_2. Dry deposition is a major sink of O_3; ozone is probably the best studied air pollutant for this reason. All of these reasons place O_3 at high priority.

Nitric acid (HNO_3) is the final product of atmospheric oxidation of nitrogen oxides. It is a strong acid, highly soluble in water. Nitric acid is thought to be dry deposited at a maximum rate governed by atmospheric transport; this assumption is consistent with its high solubility in water and presumably in the ubiquitous water-like film associated with vegetation and other terrestrial surfaces. The high acidity of HNO_3, as well as its role (often the case with nitrogen compounds) as a plant nutrient, establish the importance of characterizing its dry deposition.

Ammonia (NH_3) is not considered a direct pollutant. Sources of NH_3 are principally biological: animal wastes, fertilizer, etc. NH_3 is of interest in the wilderness area context because it is one of the principal atmospheric bases available to neutralize atmospheric acids, although it contributes to soil acidification when taken up by the plant communities. Reactions of NH_3 with aerosol H_2SO_4 results in gas-to-particle conversion that in turn affects the deposition and fate of NH_3. Additionally, NH_3, as an available nitrogen species, is a nutrient to nitrogen-poor ecosystems. Little is known about dry deposition velocities of NH_3, but they may be large in view of the high solubility of NH_3 at acidic to neutral pH. The decision to measure ammonia is not yet final.

Aerosol particles. Most of the sulfate and nitrate associated with atmospheric particles is found on particles of 0.05 to 5 micron diameter, as a result of gas-to-particle conversion. These particles can travel over long distances because of their low gravitational settling velocities and thus they are good indicators of distant pollution sources, particularly of sulfur dioxide. They are a prime cause of visibility reduction and hence of considerable concern in the wilderness area.

1.2.1.2 Wet Deposition (quality and quantity) - Table 1-2 lists the parameters to be measured in precipitation. Wet

deposition is a major pathway for the transport of nitrogen and sulfur compounds to the earth's surface. Wet deposition combined with dry (gases and aerosols) represents total deposition. Thus, precipitation quality and quantity is of major importance in determining pollution impacts on high-elevation ecosystems. Because of the remote location of wilderness areas from major pollution sources, a significant fraction of the total deposition of pollution-related material will be delivered as "wet" deposition.

Several national wet deposition networks have been in operation for several years. The installation, operation, and subsequent laboratory analysis are well established and are adapted for this protocol. All of the analyses listed in Table 1-2 are to be conducted at a central laboratory. The only variables measured at the monitoring site after precipitation collection (or within a few hours driving distance from the monitoring site) are precipitation quantity, field pH, and conductivity.

1.2.1.3 <u>Meteorological Measurements</u> - The instruments proposed for this wilderness area program are listed in Table 1-3. The accuracies specified by the manufacturers are noted. This equipment has been field tested and has been routinely used by other investigators in many monitoring programs in the past. No recommendations are made for a specific manufacturer; other manufacturers may satisfy equal performance characteristics for their instruments.

In order to assess total deposition, both wet and dry, a series of meteorological measurements are required. Meteorological variables to be measured at a representative site (outside the wilderness area) during the warm season include temperature, pressure, precipitation, wind speed, wind direction, surface wetness and relative humidity. Precipitation quantity is a particularly important meteorological variable; wet acidic deposition calculations are very sensitive to estimated precipitation amounts. While precipitation data measured at a single wilderness area station during the warm season is not representative of precipitation over the entire area, this data would be augmented by precipitation data collected at precipitation stations inside the wilderness area. The amount of precipitation over the wilderness area can be estimated from these combined data.

Wind data is collected at the same location to provide information necessary for understanding the variability in the aerometric and precipitation chemistry data, as this variability often can be attributed directly to sources upwind. Pressure and temperature data are needed for calculating volume flow rates for aerometric samples. Temperature and humidity data may be needed, along with land use data, vegetation cover data, surface wetness and other parameters, to estimate gas and aerosol dry deposition rates.

Table 1-2.

Summary of Analytes, Analysis Methods and Detection Limits for Precipitation

Analyte	Method	Time Resolution Warm Season	Time Resolution Cold Season	Quant. Detection[a] Limit	Desired Accuracy[b]
H^+	electrode	weekly ave	accumulation over season	--	0.05 pH units
Con- ductivity	bridge	"	"	--	20%
$SO4^{2-}$	IC[c]	"	"	0.2	lgr of QDL or 10%
NO_3^-	IC	"	"	0.2	lgr of QDL or 10%
Cl^-	IC	"	"	2.0	lgr of QDL or 10%
NH_4^+	AWC[d]	"	"	0.5	lgr of QDL or 10%
Na^+	AA[e]	"	"	0.2	lgr of QDL or 10%
K^+	AA	"	"	0.2	lgr of QDL or 10%
Ca^+	ICP[f]	"	"	0.2	lgr of QDL or 10%
Mg^+	ICP	"	"	0.2	lgr of QDL or 10%

[a]Defined as the minimum value that is likely to be detected by the stated method when applied to actual precipitation samples. This value is generally larger than the minimum detection limit that is achievable in the laboratory for pure standard solutions.
[b]Defined as the maximum difference between the measured and true value of the quantity in question.
[c]Ion chromatography
[d]Automated wet chemistry
[e]Atomic absorption
[f]Inductively coupled plasma spectroscopy

Table 1-3.

Proposed Meteorological Equipment List

Warm Season

Parameter	Measurement Method	Range	Accuracy
Wind speed	Cup anemometer	0.3-55.9 m/s	0.2 m/s up to 13 m/s, and not exceeding 0.5 m/s thereafter
Wind direction	Vane	0-540 degrees	3.6 degrees
Temperature	Two element composite linear thermistor	-30-50 C	0.15 C
Relative humidity	Dielectric polymer capacitance	0-100%	2%
Pressure	Capacitance aneroid	600-1100 mb	0.3 mb
Precipitation*	Weighing mechanism	0-15 cm	0.01 cm
Surface wetness	Leaf wetness grid	resistance measurement	

*At sites where a significant fraction of the precipitation is in the form of snow, an Alter-type windshield will be added.

1.2.2 Cold Season

Table 1-2 lists the analyses to be conducted on snow pack samples. The snow pack provides an accumulation and integration of deposition events of natural and anthropogenic water-soluble and particulate inputs. Total deposition of pollution-related material averaged over the entire cold season (wet and dry) can be estimated for selective sites within the wilderness area, provided that snow melt occurs only during the normal spring melt period and not intermittently during the winter. Because of the inaccessibility of most parts of the wilderness area during the cold season, seasonal total deposition may be the only measurement parameter obtained during this season.

Depending on the accessibility of the warm season monitoring site, measurements of gases and aerosols should continue during winter. The measurement of "wet" precipitation by use of the wet-only samples depends on the ability of the sampler to operate effectively under existing weather conditions. Meteorological measurements should continue throughout the cold season.

1.3 Requirements

1.3.1 Sampling Program for Warm Season

In principle, the monitoring sites cannot be located within the wilderness area. The number of required sites depends on the wilderness area under investigation. The requirements detailed here are on a per station basis. A further assumption is that a qualified central laboratory(ies) will be responsible for preparing all required materials (filters, collection bottles, shipment containers, etc.) for the field sites and analyzing the exposed filters and collected precipitation samples. The equipment needs for such a central laboratory are not detailed here, but Table 1-4 presents an overview of analytical techniques available for the analysis of both impregnated filters (from filter pack) and precipitation samples (rain and snow). Table 1-5 summarizes the instrumentation requirements for the monitoring site. All equipment or support items except the filter pack are readily available from several manufacturers. All equipment and field procedures for precipitation and snow pack samples should be (to the maximum extent possible) identical to existing national or statewide programs to insure maximum data compatibility.

No standardized equipment for filter pack systems is in use today. Both EPA and EPRI are planning the deployment of filter pack systems in 1987 as part of a nationwide gas sampling network to measure ambient concentrations. The equipment discussion which follows assumes that such networks will be implemented and filter pack equipment or annular denuders will become commercially available for this wilderness area monitoring protocol.

Table 1-4.

Expected Concentrations of Rainwater Contaminants, Laboratory Detection Limits for Selected Constituents in Rainwater (Minimum Detection Level, MDL, in ug/ml, Precision in %)

	Typical Concentration Range (ug/ml)		
Observable	Rural	Remote	IC[f]
SO_4^{2-}	3.4[a]	0.8-1.2	0.025/5%
NO_3^-	2.3[a]	0.7-1.0	0.015/5%
Cl^-	0.64[a]	0.15[c]	0.007/5%
NH_4^+	0.39[a]	--	0.011/5%
Na^+	0.31[a]	0.085[c]	0.007/5%
K^+	0.088[a]	0.02-0.04	0.016/5%
Ca^+	0.21[a]	0.2-0.5	
Mg^{2+}	0.057[a]	0.03-0.08	
Fe	0.07[k]	0.064[d]-1.57	
Mn	23-5.7[e]	0.19[e]	
Pb	44-12[e]	0.09[e]	
H^+	0.074[a]	--	
Total acidity	0.11[k]	--	
Conductivity	8.7 umhos[l]	--	

Table 1-4. Continued

Observable	AC[g]	ICP[h]	AA[f]
SO_4^{2-}	0.3/5%		
NO_3^-	0.04/5%		
Cl^-	0.02/5%		
NH_4^+	0.005/5%		
Na^+		0.002/10%	0.002/2%
K^+			0.01/2%
Ca^+		0.00007/5%	0.01/2%
Mg^{2+}		0.00005/5%	0.001/2%
Fe		0.0003/5%	0.01/2%
Mn		0.00006/5%	0.01/2%
Pb		0.008/5%	0.05/2%
H^+			
Total acidity			
Conductivity			

Table 1-4 Continued

Observable	XRF[i]	Electrode[j]	Titration[k]
SO_4^{2-}	0.04/2% (S)		
NO_3^-		0.4/5%	
Cl^-	0.02/2%	1.8/10%	
NH_4^+		0.015/5%	
Na^+	0.05[m]/2%	6.02/5%	
K^+	0.01/2%	0.04/5%	
Ca^+	0.007/2%	0.02/5%	
Mg^{2+}	0.04/2%		
Fe	0.006/2%		
Mn	0.004/2%		
Pb	0.01/2%	0.2/5%	
H^+		± ? unit	
Total acidity			0.002/3%
conductivity			0.1 umhos/<10%

[a]Average of 8 sites. MAP3S/RAINE, 1982.
[b]Guiang et al., 1984.
[c]J. Gibson, personal communication.
[d]Barrie and Vet, 1984.
[e]Range is urban-rural values. Galloway et al., 1982.
[f]Desert Research Institute Lab results.
[g]Technicon, Inc. specified limits.
[h]Fassel and Knisely, 1974.
[i]Assumed 47 mm filter, 5 ml rinse using protocol 5 detection limits as specified by NEA labs.
[j]Orion specific ion electrode, MDL as specified.
[k]Monthly average values from Chan et al., 1983.
[l] ?????

Table 1-5.

Summary of Basic Equipment Needs for Monitoring Site

Equipment	Time Resolution	Man Days Requirment at site*
	WARM SEASON	
Precipitation		
Special bucket with lid opened automatically by rain	events averaged over one week	0.4 per week
Aerometric		
Filter pack** - Teflon nylon oxalic acid impregnated	averaged over one week or day/night (12-hr schedule) averaged over one week	0.3 per week
Ozone - uv photometry	(1-hr schedule)	0.2 per week
Meteorology	(all 15 min or 1-hr average)	0.1 per week
Wind speed:cup anemometer Wind direction:vane Temperature:resistance thermometer Pressure:capacitance aneroid barometer Precipitation:weighing rain gauge Relative humidity by polymer capacitance sensor		
Support Equipment		
Data logger for meteorology, ozone Triple beam balance pH meter Conductance bridge Calibrator for gas monitor (ozone) Supplies		

Table 1-5. Continued

Equipment	Time Resolution*	Man Days Requirment at site*
	WARM SEASON continued	
<u>Shelter and Tower</u>		
10-meter tower for met instrument and air intake		
Instrument shelter with AC/heat capable of maintaining temp.		
Security fence		
Access road		
Power access		
	COLD SEASON	
<u>Snow Pack</u>		
Standard Federal Sampler	seasonal average collection before snow melt	1 week per station
<u>Support Equipment</u>		
Refrigerator for transporting snow samples		
Balance		
Supplies		

*Exclusive of travel to and from site.
**Require fabrication for samplers, not yet routinely available as an "off the shelf" item.

The filter pack air sampling method uses selective filters within the filter pack to collect specific pollutants over a 12-hour to 7-day period, depending on protocol. The filter packs are sheltered in a sample head which is permanently attached on a support pole at a height of 7 meters.

With this pack of sequential absorbing filters, the average concentration (12 hr up to one week) of fine particles (SO_4^{2-}, NO_3^-, NH_4^+) and gases such as SO_2, HNO_3, NO_2, and NH_3 can be monitored. When the air stream is drawn through a size selective inlet, particles of a specified size range can be captured. Various choices exist for the selection of filter media, absorbent, flow meters, and size selective inlets. Although filters are not considered an equipment item, they are discussed because they are an essential part of the system.

Teflon membrane filters will be used to collect the particles before the air stream encounters other filters. Teflon has been shown to quantitatively pass HNO_3 (Golden et al. 1983), although nitrate particles collected on the filter may volatize (Appel et al. 1984). The Desert Research Institute (DRI) currently is evaluating a ringed Teflon membrane filter manufactured by Pallflex Corporation at one-third the cost of the Gelman Membrane Product. Preliminary analyses of the chemical blanks of these filters by the U.S. EPA and NEA labs indicate equivalently low levels of trace elements. Although these filters are analyzed only for sulfate and nitrate as part of the wilderness protocol, they are selected and sectioned so that more extensive chemical analyses can be performed on them at some later date. (X-ray fluorescence analysis for elemental species might be useful for regional receptor modeling, for example.)

Nylon membrane filters are used to capture <u>nitric acid</u> (HNO_3). The specificity of Nylon for HNO_3 capture has been demonstrated in both laboratory (Miller and Spicer 1975; Spicer et al. 1978) and field studies (Spicer et al. 1982). Nylon does not remove NO_2 or PAN but may absorb N_2O_5 at high humidities. When located downstream of the Teflon filter, it also absorbs any HNO_3 and some of the SO_2 that may be volatized from the particulate collection. Nylon membrane filters (Ghia Nylasorb) have been used to trap nitric acid quantitatively (Spicer 1979).

Some concern exists regarding the availability of Nylon membranes and the quality of new formulations. An alternative to Gelman's Nylasorb product (undergoing reformulation) is Nylon 66 from Sartorius.

A filter impregnated with triethanolamine (TEA) absorbs <u>nitrogen dioxide</u> (NO_2). A high collection efficiency for NO_2 has been demonstrated in a project conducted by DRI for Southern California Edison. The TEA filter will measure time-averaged low concentration NO_2 (Levaggi et al. 1973; Durham and Ellestad 1984).

A KOH-glycerol impregnated cellulose fiber filter has been shown to be an effective trap for sulfur dioxide (SO_2) (Hugen 1963), while oxalic-acid-impregnated glass fiber filters have been used to collect ammonia (NH_3) (Richards and Johnson 1979). KOH also collects nitric acid with virtually 100% efficiency and thus could be used in a dual role in place of Nylon.

Various options are available for a system which passes samples of the atmosphere through these filters. For the wilderness area, application of a heated Teflon-coated cyclone that removes particles larger than 2 um aerodynamic diameter is proposed.

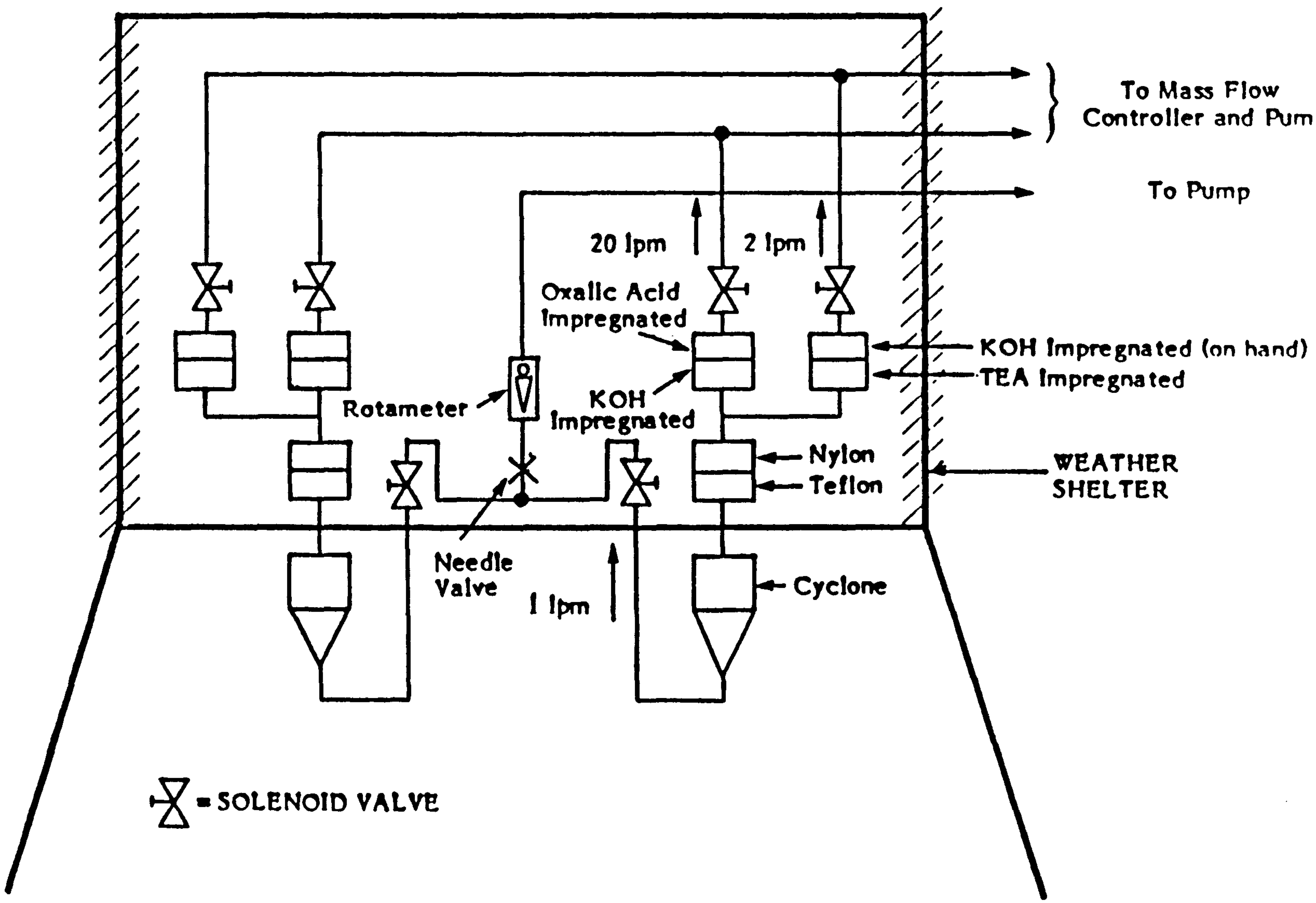
The cyclone assembly is housed in a weather instrument shelter as shown in Figure 1-1. The cyclone inlet is protected from precipitation but able to sample air directly. A minimum length of Teflon-coated pipe is used to direct the sample streams to the filter packs, located inside the shelter. The mass flowmeters and pump are located in a separate pump box. When replicate sampling is necessary, a second complete filter pack system and shelter can be colocated.

Filters required for filter pack sampling must meet the following requirements: 1) mechanical stability, 2) chemical stability, 3) low flow resistance, 4) good retention without clogging, 5) low and consistent blank values for the species being measured and those which might additionally be measured, and 6) reasonable cost and availability.

Ambient ozone (O_3) concentration is measured with a UV photometric type instrument such as a Dasibi Environmental 1003-AH ozone monitor or the equivalent model TECO 49P. The Dasibi UV absorption photometer measures the amount of ultraviolet radiation absorbed by ozone in a sample of ambient air. The quantity of light absorbed is proportional to the concentration of ozone in the air sample. Ozone concentration readings are digitally displayed on the front panel over the range of 0.000 to 1.000 ppm. An analog output of 0-1 VDC also is connected to the data logger.

Sample gas is continually supplied to the sample chamber by a self-contained pump and sample handling system. The intensity of the UV beam traversing the sample cell is attenuated in proportion to the ozone concentration in the sample. The signal is detected and electronically processed for presentation by the readout system and output to the data logger. Two reference subsystems provide a high degree of stability by correcting for source intensity, optical path transmittance, and detector response changes. Self zeroing and interference removal are accomplished by comparison of sample and reference readings. If the operating parameters of the analyzer are within specifications, no span or zero drift occurs and the analyzer is self-calibrating.

Filter Pack Flow Diagram



Mounting of filter pack system.

Figure 1-1.

1.3.2 Cold Season, Snowpack Sampling

Several standardized tools are available for collecting snow cover. Table 1-6 summarizes the properties of snow samplers used in North America.

Tests suggest that a sharp "Federal sampler" is suitable for use in all types and depths of snow cover. Cooperative testing by North American agencies through the Western Snow Conference is continuing in an attempt to develop a standard metric sampler that will provide consistent accurate and repeatable measurements for deep and shallow snow covers (Farnes et al. 1980). Currently, the "Standard Federal" is the preferred choice throughout the western U.S. and Canada. Experience indicates that in deep snow packs (> 4-5 m depth) with numerous ice lenses, the Standard Federal corer is not sufficiently robust for repeated coring during a single field trip. This is especially true for coring in cold, continental snow packs such as those found in the Rocky Mountain region. In such cases, a McCall corer should be used. Cross-calibration to Standard Federal core sampling efficiency has been reviewed by Farnes et al. (1980).

1.4 Field Procedures

1.4.1 Sampling Site Selection Criteria--Warm Season

1.4.1.1 Regional considerations - Because of the difficulties in operating monitoring sites within the wilderness area, "representative" locations will be chosen for sites at the periphery of the area. "Representative" in this context refers to the climatology of the region and to the synoptic scale air mass flowing over the wilderness area. Both of these overall meteorological parameters should be assessed in conjunction with manmade pollution sources in a roughly 500-mile zone surrounding the wilderness area to determine approximate locations for potential monitoring site(s). Ideally, such an assessment should yield monitoring site(s) that can characterize the flow of pollution-related material into and out of the wilderness area. The number of monitoring sites must be established on a case-by-case basis and obviously depends on the size of the wilderness area, the complexity of terrain, the acceptable level of uncertainty, etc. Determining an appropriate number of sites is not an easy task.

1.4.1.2 Local considerations

Power. The most important criterion is the availability of electrical power because most of the atmospheric samplers require at least 110 V of electricity.

Location. Within the constraints set by the availability of power, the location of a sampling site should be as close to the actual remote area of interest as possible. In addition to a

Table 1-6.

Snow Sampler Properties

	Standard Federal[a]	Federal[b]	Bowman[c] L-S	McCall[d]	Canadian[e] MSC	Adirondack[f]
Material	aluminum	aluminum	plastic or aluminum	heavy gage aluminum	aluminum	glass fiber
Length of tube[g] (cm)	76.2	76.2	76.2	76.2	109.2	153.7
Theoretical ID of cutter (cm)	3.772	3.772	3.772	3.772	7.051	6.744
Number of teeth	16	8	16	16	16	None[h]
Depth of snow that can be sampled (m)	<5	<5	>3.5	>5	1.0	1.5
Retains snow cores easily	yes	yes	yes	yes	no	no

[a]Standard sampler used in the Western United States and Canada.

[b]Identical to "Standard Federal" but has an 8-tooth cutter.

[c]Cutter has alternate cutter and raker teeth and may be mounted on plastic or standard aluminum tubing. It is more an experimental rather than operational sampler.

dUsed in dense snow or ice. It is a heavy gauge aluminum tube with 5-cm cutter with straight flukes. It may be driven into the pack with a small slide drop hammer producing an icepick effect.

[e]Atmospheric Environment Service large diameter sampler used in shallow snowcover.

[f]Large diameter fiberglass sampler commonly used in Eastern United States

[g]Most snow samplers in North America use inches and tenths as their basic units of measurement. Values in this table are corresponding metric equivalents.

[h]Stainless steel circular cutter edge or small teeth.

sampling location at or near the remote site itself (if possible), at least one sampling location should be upwind of the remote site based upon the prevailing winds in the area. The temporal variation of atmospheric concentrations of interest is probably much greater than the spatial variation, particularly in background locations; however, at least two upwind sampling sites probably should be operated to serve as a check on one another and provide backup information if one site should become inoperable.

The selection of the atmospheric sampling site also should depend on potential local sources of pollution. Potential local sources of pollution include home chimneys, vehicular traffic in maintenance yards and parking lots, auxiliary diesel generators, and small local industrial activities that might be present in back-country areas. Seasonal changes in activities producing potential pollution sources also should be noted.

Access. Because of the size of some of the equipment and the need for servicing on a year-round basis, the site should have reasonable access, i.e., one should be able to drive close (0.5 km) to the site during various weather conditions.

Site Protection and Security. The site should be protected from unauthorized entry. The first line of defense is to locate the site out of view of normal unofficial traffic and passersby. Other ways to protect the site include the following:

1. Locate a place with a permanent resident on officially protected property such as a ranger station, a university field station, etc.

2. Fence the site.

3. Place signs around the site explaining its purposes and asking people to stay away.

Experience indicates that the most effective protection of a site is to keep it out of everyday view.

Vegetation and Topography. Ideally, the best site location has a complete ground cover to help minimize resuspended materials and dust from the local area. In addition, the site should never be placed under or near overstory vegetation. As a rule of thumb, the diameter of the site should be about 10 times the average height of the surrounding overstory vegetation. The site should be located so that sampling will reflect, as accurately as possible, the chemical constituency of air masses of fairly large circulation.

Staff. Ideally, the site should be located where year-round staff are available to service the equipment and change the sampling heads. Experience indicates that this means someone living on-site or a local person who can get to the site in less than a 30-minute drive.

Tradeoffs in Site Selection. Many atmospheric sampling sites may not have all of the desirable attributes. Some compromises must then be made between the ideal and what is available. To evaluate these tradeoffs, some kind of a systematic decision-making process should be used.

One technique that has proved useful in making site selections is a Kepner-Tregoe procedure. In this type of procedure, site criteria are divided into "musts" and "wants"; those criteria which must be met, and those criteria which are desirable to have. A ranking procedure begins based upon the "musts" and "wants," and a final decision is made by a group of experts in atmospheric sampling.

The site criteria are summarized in Table 1-7. The instruction manual issued by NADP (NADP 1984a) provides further information regarding the establishment of a wet deposition site using the wet/dry precipitation collector.

1.4.2 Sampling Site Selection Criteria for Snowpack (Cold Season)

Total deposition of pollutant-related material accumulated in snow over the entire cold season will be monitored at sites within the wilderness area. The number of snow cores to be sampled varies with the size of the wilderness area, the extent of ecologically sensitive regions, the complexity of the terrain, and other factors, but a minimum of 5 samples should be taken at each site.

Sampling of the snowpack should be carried out at maximum accumulation, but before spring melt starts. These ideal conditions are not always met. The Cascade and Sierra Nevada Mountains have a warm snowpack with temperatures usually near 0^{o} C (Smith 1974). Because of air temperature variations, some melting of the snowpack may occur during the winter, and depending on temperature conditions, rain may fall on the snowpack and percolate through it. Such percolation, if it continues through the entire depth of the snowpack, can leach soluble material from the snow in concentrations disproportionate to those in the snowpack (Johannessen and Henriksen 1978; Johannessen et al. 1980; Hibberd 1984). In addition, atmospheric conditions under which the snow was deposited, the degree and type of metamorphism the snow has undergone, and the intensity of rain and/or melt events all can influence the rate at which impurities can be removed from the snow (Shockey and Taylor 1984). Thus, the snowpack cannot be assumed to accumulate and hold all atmospheric deposition during the life of the snowpack.

To lessen the possibility of rain and melting impacts, sampling sites should be located above 2000 meters and sampling should occur in late winter before the spring snowmelt begins. Whenever possible, the sampling sites should be located in the

Table 1-7.

Site Selection Criteria for Representative Aerometric Station (Warm Season) Outside of Wilderness Area

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General Criteria

- The site(s) should be selected to give samples representative of the wilderness area.
- The site(s) must be accessible during the warm season in all weather conditions on a daily basis.
- The site(s) must be located in an area secure from damage by animals or vandals.
- The site(s) must be serviceable by line power and either have a suitable equipment shelter or have room for a suitable shelter.
- Sampling site(s) should be situated no closer than 20 km from areas enclosing combined sources larger than 10,000 tonnes/yr SO_x or NO_x.
- Sampling site(s) should be located at least 5 km from population centers greater than 5,000, at least 10 km from population centers greater than 50,000.
- All candidate sites must appear to meet the detailed selection criteria listed below.
- The landowner or custodian must be in full agreement with the intended use of the site (including any restrictions on access or use that may be required) and willing to grant the access and space needed to fulfill the sampling requirement for the lifetime of the network.

Specific Criteria

- All large objects that might contribute to the contamination of precipitation samples must be farther than two times their height from the sample collector or fall below a 30 degree elevation angle when viewed from the collection point.
- Small objects, such as vegetation or fences, that are of comparable height to the height of the precipitation collector opening must either be farther than two times their height from the collector or be at a distance equal to the height of the collector opening--whichever distance is greater.

Table 1-7. Continued

- Whenever possible, the precipitation sample and all intakes to aerometric monitoring equipment must be located a minimum of 250 meters from all public roads or other routing mobile sources of atmospheric pollutants.

- All sampling sites should be located a minimum of 250 meters from any fertilizer storage areas, feed lots, fuel storage areas, stationary internal combustion engines, or other similar sources of potential contaminants.

- Sources of dust, such as construction areas and tilled farm lands, should be avoided whenever possible. If this restriction cannot be met, these sources should be kept at least 250 meters, from the sample locations.

- All possible efforts should be made to locate monitoring sites on level, naturally vegetated land or in grassy areas. No site should have a slope greater than 20 degrees from the horizontal.

- All sites must be accessible by vehicle.

- All sites must be located outside the wakes of buildings, trees, or abrupt changes in terrain.

- All sites must have clean, temperature-controlled working area set aside for sample processing. The area should be dedicated to the handling of precipitation samples and it must not contain any potential contaminants.

southwestern part of meadows or in open areas where shading minimizes surface melting from solar radiation. In areas below 2000 meters elevation, the temperature of the snowpack may reach 0^{o} C and therefore endanger the integrity of the snowpack. To minimize selective leaching of ions from the snowpack, waterproof boxes of about 2x2 m and lined with polypropylene plastic[1] could be set out in the fall. Snow cores can be collected from the snow column inside and outside of the boxes during the later winter sampling period.

1.4.3 Sample Collection Procedure (Warm Season)

1.4.3.1 Filter pack - Every seven days (when samples are removed from the precipitation collector), the filter pack is removed and a new filter pack is installed. Standard Operating Procedures (SOP) will be developed by EPA and EPRI contractors during 1987. The following is a preliminary description of the procedures to be followed.

Changing filter packs (proposed). The final protocol will depend on the selection made for the national programs.

1. Check the flow rate as indicated on the sampler control module digital readout. Obtain the actual flow rate from the calibration sheet that corresponds to the indicated value from the sampler. Record this value on the "OFF Flow Rate" in the log book and sample record sheet.

2. Note the time on the data logger display. Record this time as the "OFF time" in the log book and sample record sheet.

3. Lower the sample head by releasing the cam lock at the base of the tower and slowly feeding out the line tied to the tower upright.

4. Remove the filter packs by pulling up on the quick connect fittings collar. Place the filter packs in zip lock bags.

5. The quick connect fittings seal themselves off when no filter is installed, this will check the system for leaks. After one minute, check to see that no flow is indicated on the control module digital readout.

6. Install the new filter packs by pushing them into the quick connect fittings in the base plate. The "sample" filter pack should be installed in the fitting marked SAMPLE and the blank filter pack should be installed in the fitting marked BLANK.

---

[1]Polypropylene is not the appropriate material for collecting snow for subsequent metal analysis.

7. Raise the tower by pulling on the line attached to the end of the tower upright. Secure the upright into the tower base plate and engage the cam lock.

8. Note the time indicated on the data logger display. Record this time as the "ON TIME" in the log book and sample record sheet.

9. Check the flow as indicated on the control module digital readout. If necessary, adjust the flow to the value corresponding to a flow rate of 1.5 liters per minute from the sampler calibration sheet. Record this value as the "ON Flow Rate" in the log book and sample record sheet.

Filter Pack Handling and Shipment. After removal, the complete filter pack is sealed on both ends with plastic screw caps, placed inside a zip lock bag, tagged, and shipped inside a padded box to the Central Analytical Laboratory. The following information should be recorded in the station logbook and on the sample identification tag which will be attached to the zip lock bag containing the filter pack:

1. Filter No.: Record the sample number as it is written on the filter pack.

2. Site ID: Record the station identification number.

3. Start Date/Time: Record the calendar date and the time that the sample period started.

4. Stop Date/Time: Record the calendar date and the time that the sample period ended.

Standard Operating Procedures are currently developed for all phases of the field sampling collection by EPA (Dr. Steve Bromberg) and Atmospheric Environment Service, Canada (Dr. Len Barrie).

1.4.3.2 Precipitation - A SOP for the measurement of wet deposition exists for all major national networks, i.e, MAP3S, UAPSP, and NADP/NTN. The SOP for NADP/NTN will be adopted here. Operational steps including bucket changing and weighing, sample storage, field and laboratory analysis (pH and conductance measurement), shipment, and maintenance are detailed in the NADP site operation manual (NADP 1982).

In summary, the NADP/NTN protocol is the following:

1. An Aerochem Metric Model 301 wet/dry precipitation collector is installed for collection of precipitation samples and a Belfort recording rain gauge is installed to measure daily precipitation amounts.

2. Samples are collected weekly (52 or 53 samples a year).

3. The sample is weighed at the site to determine total precipitation volume.

4. A 20 milliliter aliquot is removed from the sample on which field laboratory and pH measurements are made.

5. A form is filled out by the site operator describing the sample and the collection characteristics (see Figure 1-2).

6. The sample is mailed in the sealed collection container along with the sample reporting form to a central laboratory for analysis.

Because of the dilute nature of the precipitation samples, sample handling procedures must be followed carefully to prevent sample contamination. These procedures are presented in detail in the NADP/NTN manual. In addition to detailing site operation procedures, the manual contains information for equipment trouble shooting. This plan will be adopted for the operation of the monitoring sites, with the exception of those sections which refer specifically to liaison with the NADP/NTN Central Analytical Laboratory (CAL).

1.4.3.3 <u>Ozone</u> - An SOP exists for all aspects of ozone measurement, calibration, and preventive field maintenance. They are detailed in, and part of, the owner's manual supplied by the equipment manufacturer (either TECO or Dasibi).

1.4.3.4 <u>Snowpack collection procedure</u> (cold season) - The snow sampler is lowered vertically into the snowpack with a steady thrust downward. A small amount of twisting aids in driving the tube and cutting thin ice layers but considerable force and twisting of the sampler with a driving wrench may be required to penetrate hard layers of ground ice. Penetration to extract a soil plug helps to prevent the loss of the snow core from the tube, and a trace of soil or litter in the cutter indicates no loss has occurred. Observation of the length of the snow core permits a quick assessment of whether a complete core has been obtained, the depth of snow having been measured previously. Compaction of the snow core will occur during sampling, the amount depending on snow conditions. Blocking of the core or freezing of the snow may also occur in the tube, preventing snow from entering. In such cases, the core should be discarded and another sample taken. Freezing in the tube is a problem that occurs when the snow temperature is below 0° C and the air temperature is above 0° C. When a good snow core has been obtained, the sample is weighed in the tube and the combined weight (in water equivalent units) is read directly with a spring balance. The tare weight of the tube is subtracted to obtain the snow water equivalent.

The density of the snow is determined by dividing the water equivalent by the depth of the snow. Of these three parameters, density will general show the least areal variability.

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM

A Cooperative Research Program of the State Agricultural Experiment Stations and other Federal, State and Private Research Organizations • IR-7

NADP/NTN FIELD OBSERVER REPORT FORM

Send Completed Form With Each Bucket To The Central Analytical Laboratory

BUlk		LD	
DA		NA	
QA		NN	
NS/Exclude		SP	

1. STATION

Name ____________________

ID

2. OBSERVER

Signature

Initials

3. SAMPLE BUCKET

Check One Wet-Side Dry-Side

4. BUCKET ON

Date: MO DAY YR

Time: 0000-2400

BUCKET OFF

Date: MO DAY YR

Time: 0000-2400

These Times Are: *Check One* Standard / Daylight Savings

5. SITE OPERATIONS

Check Yes or No for each item for Wet-Side samples only

If No, explain in data Block II, Remarks

YES	NO	
2	1	1. Collector appears to have operated properly and sampled all precipitation events during entire sampling period
2	1	2. Rain gage appears to have operated properly during the week
2	1	3. Collector opened and closed at least once during the week, other than for testing

6. SAMPLE CONDITION

Check Yes or No for all samples containing precipitation

Describe all else in Data Block II, Remarks

YES	NO	
2	1	1. Bird Droppings
2	1	2. Cloudy or Discolored
2	1	3. Unusual amounts of soot or dirt for this site

7. SAMPLE WEIGHT

For all buckets containing precipitation

Bucket + Lid + Sample

− Bucket + Lid

= Sample Weight in grams

8. PRECIPITATION RECORD

For Wet-Side Samples Only

R - Rain Only
S - Snow Only
M - Mixture
U - Unknown
Z - Zero
T - Trace
MM - Missing

Bucket On ← To → Bucket Off

	TUES	WED	THUR	FRI	SAT	SUN	MON	TUES
Type Circle one	R S M U	R S M U	R S M U	R S M U	R S M U	R S M U	R S M U	R S M U
Inches or circle one	Z T MM	Z T MM	Z T MM	Z T MM	Z T MM	Z T MM	Z T MM	Z T MM

Total sampling period precipitation from rain gage ______ Inches

Total precipitation from sampler = Sample Weight × 0.00058 inches/gram ______ Inches

9. SAMPLE CHEMISTRY

Only for Wet-Side buckets with Precipitation

MO DAY

Aliquot Removed in mls

Conductance In μS/cm

Distilled Water

7 5 . 0 Standard Certified ÷ Standard Measured = Correction Factor

Correction Factor × Sample Measured = Sample Corrected

pH

Precipitation Sample

pH Check Sample

10. SUPPLIES

Circle if needed

- pH 4 Buffer
- pH 7 Buffer
- pH Check Sample
- 75 μS/cm Standard
- Field Forms

11. REMARKS

For example: Insect contamination, contamination by operator, equipment malfunction, harvesting in area, etc.

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Figure 1-2.

Table 1-8 illustrates a convenient format for recording snow survey information in the field. Such a form also provides documentation of any problems encountered while surveying that may affect the accuracy of the survey and the interpretation of the results.

All snow samples should be double bagged in polypropylene, (after dirt or soil has been carefully removed from bottom) heat sealed, and kept frozen by mechanical refrigeration until they are analyzed in a designated chemical laboratory.

1.5 Laboratory Sample Analysis

1.5.1 Filter Pack

Development of an SOP currently is being funded by EPA and EPRI as part of the implementation of a dry deposition network. The SOP will describe the processing of filter samples from initial acceptance testing through laboratory analysis of the filter extracts. The acceptance criteria and the manner in which acceptance testing is conducted will be specified in the SOP. All filters that pass acceptance testing are then weighed, packaged, numbered, and sent to the sampling sites.

Upon receipt at the laboratory, each filter is weighed and a certain fraction (specified by the SOP) is reweighed separately. All filters passing quality acceptance tests are chemically analyzed by laboratory processes analogous to those used for precipitation samples.

The preliminary analytical procedures for extracting and analyzing filter pack samples are contained in the following SOP's (U.S. EPA):

- EMSL/RTP-SOP-QAD-531, Extracting and Analyzing Dry Deposition Samples, May 14, 1985.

- EMSL/RTP-SOP-QAD-503, Analysis of Anion Samples by IC, January 30, 1985.

1.5.2 Precipitation

All sample aliquots arrive at the central laboratory in special containers on a weekly basis. Standard Operating Procedures exist for all phases of analysis and quality control. This wilderness area protocol eventually will include the procedures outlined in "Development of Standard Method for the Collection and Analysis of Precipitation", Illinois State Water Survey, Analytical Chemistry Unit, EPA Contract No. CR810 780-01-1. March 1986 (Authors: Peden et al.).

1.5.3 Laboratory Sample Analysis--Snowpack

Analysis should be carried out at a central laboratory. To ensure uniform handling, the melting, filtration, and bottling

Table 1-8.

FORMAT FOR RECORDING SNOW SURVEY INFORMATION

Snow Course No. ________________

Name ________________________

Sampler __________ **Date** __________

Station No.	Snow Depth cm	Weight Tube & Core	Wt. Tube Only Before Sampling	Water Equivalent cm	Core Length cm
Total					
Average					

Checked ________________ **Date** ________________

SNOW SAMPLING: **Began** ________ **a.m. p.m.** **Ended** ________ **a.m. p.m.**

Sampling Conditions

(Please *check* items descriptive of present conditions)

Weather at time of sampling: **Temp.** ________ **°C**

________**Clear** ________**Snowing**

________**Partly Cloudy** ________**Blowing**

________**Overcast** ________**Freezing**

________**Raining** ________**Thawing**

Snow Conditions at Snow Course

________________**Crusted-supports man on skis/snowshoes.**

________________**Breakable crust-breaks under man on skis/snowshoes.**

________________**Snow soft and powdery-not sticky.**

________________**Snow soft and wet-sticky.**

________________**Snow samples obtained easily.**

________________**Snow samples obtained with moderate difficulty.**

________________**Snow samples obtained with extreme difficulty.**

________________**Ice layer on ground. How thick?** ________**cm**

________________**Ground frozen under snow.**

________________**Ground not frozen under snow.**

________________**Ground dry under snow.**

________________**Ground damp under snow.**

________________**Ground wet (saturated) under snow.**

General Snow Conditions

What elevation is snow-line generally? ________**m**

Is snow melting on north and east slopes? ________

Is snow melting on south and west slopes? ________

How many centimetres of fresh snow at snow course? ________**cm**

Is there evidence of snow-slides? ________

Weather conditions of past month

________**generally overcast and stormy.**

________**generally clear and cold**

________**generally clear and melting.**

REMARKS: ________________________________

process should follow strict protocol (Shockey and Taylor 1984). During melting, the overall temperature of the sample never exceeds 4° C. This procedure will minimize any bacterial deterioration of the nutrient constituents. Immediately after thawing at the central laboratory, the samples should be filtered, preserved, and bottled.

Because low, near-detection-limit concentrations of solute are expected in the snowpack from remote regions extraordinary care must be taken in sampling, processing, and analysis, as well as in collection of many samples, if a valid picture of total deposition is to be obtained. Such standard operating procedures must be developed as part of a quality assurance plan. The procedures for analysis of the melted snow are analogous to those used for precipitation samples.

1.6 Support Needs

1.6.1 Data Collection from Continuous Monitors

Measurements made by continuous monitors are collected on a data logger at each site with back up by strip chart recorder. The logger should be a Campbell Scientific Model CR21X|L or equivalent. The collection of continuous data is designed to 1) compute accurate averages or sums by regular sampling of the data channel, 2) allow checking of data on a regular basis to spot deviations from expected operation, and 3) retrieve the data efficiently.

The averages (1-hr averages) are computed in the data logger from scans made at 5-second intervals. The variables scanned are wind speed and direction, temperature (ambient and shelter), relative humidity, pressure, precipitation amount, and ozone concentration. Status channels will indicate when calibrations or zero/span checks occur, position of the lid on the precipitation bucket, and site service by a door alarm (checked to assure that routine site visits are being performed by the site technicians). The averages are stored in the data logger and on magnetic media for later retrieval. The data are available for inspection and retrieval both on-site and remotely by telephone if a telephone link is conveniently available.

The data acquisition system is illustrated in Figure 1-3. The channels are scanned every 5 seconds. Flags will be placed on variables which have yielded less than 200 valid observations for a 60-minute period because this average is considered potentially invalid. Magnetic media will be collected on a weekly basis (or daily by telephone polling if available). Strip charts serve as the final backup if the data logger should fail. Strip charts will be changed every two weeks and archived for referral as needed. Strip charts are necessary if compliance with standard QA/QC procedures are considered essential.

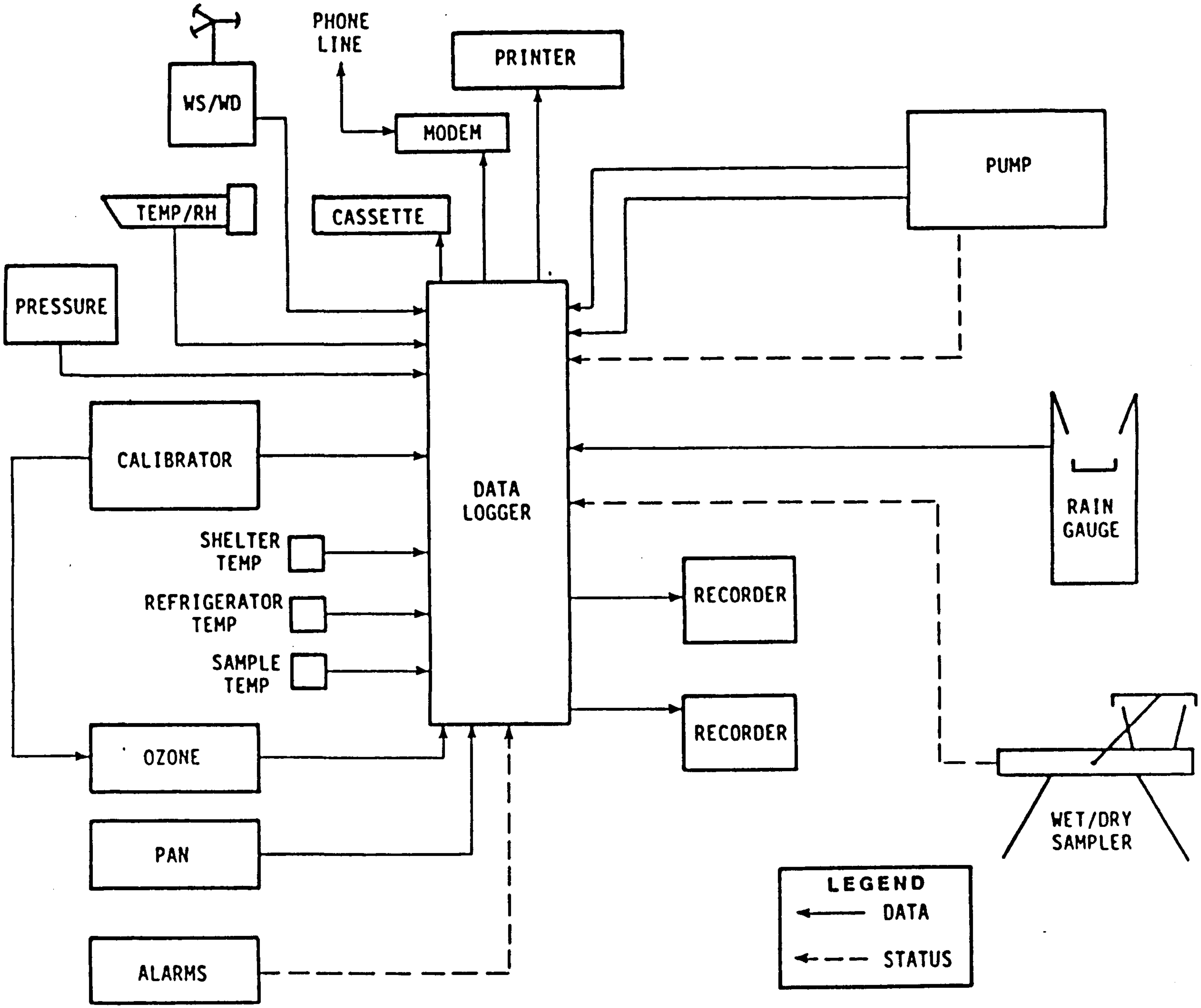
PHONE LINE
PRINTER
WS/WD
MODEM
PUMP
TEMP/RH
CASSETTE
PRESSURE
DATA LOGGER
CALIBRATOR
RAIN GAUGE
SHELTER TEMP
REFRIGERATOR TEMP
SAMPLE TEMP
RECORDER
RECORDER
OZONE
WET/DRY SAMPLER
PAN
LEGEND
DATA
STATUS
ALARMS

Figure 1-3.

The polled data should be examined by experienced personnel to detect any instrument problems and suspect data that need to be checked or validated at the site. The data should be processed at a designated processing center and checked for range validity, rate of change, and other automatic checks programmed into the data archive system. Flags are assigned to suspect data. All flagged data should be examined by an experienced data technician. The technician reviews the magnetic media or strip charts as necessary to validate questionable data. The data are summarized each month. Quality control is achieved by checking in the field and at the central location. Protocols for QA/QC are available from several field programs--past or present.

1.6.2 Quality Assurance

The aerometric, precipitation and snow core data collected by the site personnel should be of a quality consistent with the requirement of impact assessment. Achieving this goal will requires a well-conceived quality assurance plan and rigorous adherence to this plan throughout all operational phases of wilderness measurement (NADP 1984b).

Quality assurance can be divided into two types of activities: quality control and quality auditing.

Quality control consists of a set of mandatory procedures to be followed during the design, collection, and analysis phases of a measurement program. These procedures are designed to insure that the data from the program meet a predetermined set of performance criteria. Quality control activities also provide the information needed to determine the uncertainty in the measurements, i.e., precision and accuracy. Quality control is therefore an ongoing activity performed by the persons actually making the measurements.

The performance of instrumentation and laboratory procedures may be evaluated by comparison with NBS-traceable standards or by the analysis of blind samples. The performance of data processing procedures is tested by independently processing representative sets of measurements by an auditor.

1.7 Data Analysis

The monitoring protocol outlined for the wilderness area provides aerometric and precipitation data sets with known accuracy and precision. The accuracy and precision of analytical measurements of air or precipitation samples are evaluated, in principle, in the following manner: (1) accuracy is determined by analyzing EPA and NBS reference samples, unknown reference samples, and spiked samples; (2) precision is determined by analyzing replicated filter or precipitation samples.

The aerometric measurements are reported as concentration in parts per billion (ppb) by volume and in micrograms per cubic meter (ug/m^3), averaged over a time period of seven days. (The

protocol is still open as to the sampling mode, i.e., separate day-night samples averaged over one week or one week total average).

The precipitation measurements (warm season) are reported as concentration in micromole per liter (umole/l), averaged over the weekly sampling period. The total precipitation volume accumulated during one week is reported in milliliters (ml). Precipitation amount is recorded separately by the rain gauge as millimeters per day. The snowpack samples are reported as concentration averaged over the entire accumulation time. The total amount of snow accumulated is presented in snow depth, water equivalent, and total volume of water (liters).

From these primary data, one can derive dry and wet deposition data that are of interest to ecologists. In addition, the air quality at the boundary of the wilderness area can be established. This allows estimates to be made for the air quality within the wilderness area by combining the locally measured meteorological parameters with the synoptic scale air flow obtained from standard weather stations.

Dry deposition is the turbulent exchange of trace gases and aerosols from the air to the surface and the gravitational settling of particles. Dry deposition is a subset of a transfer process known as atmosphere/surface exchange. An understanding of such processes is needed for two basic reasons: 1) to specify the rate at which the atmosphere is being depleted and 2) to determine the rate of input of materials to the underlying surface.

Concern over the deposition of acidic and acidifying substances has led to an awareness of limitations in the current ability to monitor dry deposition. At present, relatively few programs are designed to produce dry deposition flux estimates, in contrast to the existence of several networks that produce wet deposition fluxes. The delay in setting up dry deposition monitoring networks primarily is due to the scientific uncertainty concerning the necessary measurements. No unequivocally accepted method exists for monitoring dry deposition.

Measurements cannot be made routinely of dry deposition at the surface itself. Methods based on computing dry deposition from other terms in area-wide budgets (e.g., using "calibrated" watersheds) have problems resolving the important terms with sufficient accuracy to yield statistically significant fluxes. However, methods based on measurements of the rate of accumulation of deposited material on natural surfaces show considerable promise, especially for particles. These techniques specifically include snowpack accumulation as proposed here.

Because of the lack of a widely-applicable method to measure fluxes routinely at the surface itself, dry deposition rates are usually inferred from data obtained in the air above the surface.

The critical assumption in this approach is that fluxes measured above the surface are the same as those at the surface, an assumption that depends on the homogeneity of the surroundings.

The deposition velocity, vd, if known, provides a convenient method for deriving the deposition flux, F, from measurements of concentration in air, C: F = vd C. This calculation is the basis for the inferential or "concentration-monitoring" method. However, the deposition velocity is not fixed for each pollutant species and surface of interest. In reality, values of vd are site-specific and time-varying. For this reason, knowledge of the land use and vegetation cover within the wilderness area is essential to associate "appropriate" situation-dependent deposition velocities with the measured, ambient pollutant concentration.

Since the air quality parameters have been measured at another location (at the periphery of the wilderness area), the dry deposition flux as derived in this protocol can only be used as a rough guideline to indicate whether or not an ecological problem may exist due to the influx of pollutants. As a rough guess, the dry deposition fluxes estimated on the basis of this protocol may be accurate only to a factor of two, whereas the concentration values exhibit a significantly higher accuracy and precision.

On the other hand, wet deposition and total deposition (snowpack) may be obtained with uncertainties less than 50%, particularly if local precipitation amount is known. Wet deposition is derived as the product of concentration and rainfall amount (warm season). Total deposition accumulated over the cold season is obtained directly from snow depth (water equivalent) and measured concentration of pollutant material in the snowpack.

1.8 Visibility

Visual range in class I areas such as wilderness is protected under the provisions of the Clean Air Act of 1977, which stipulates that the visibility within class I areas is not to be degraded and, if possible, is to be brought back to pristine levels. The measurement of this variable can be made by several different instrumental techniques. All except one, photography, require substantial amounts of power, labor, or complex data acquisition and storage. Therefore, for this application, photography was selected as the only viable measurement system.

1.8.1 Photographic Visibility System

The photographic technique, first proposed by Steffans (1949) and later refined by Johnson et al. (1985) and Hoffer et al. (1982), offers simplicity in the data acquisition with the added advantage that all the quality assurance and quality control occurs in the data reduction and analysis.

Through the picture record, the camera provides the following:

1. The general conditions of the sky and terrain features at the time of exposure;

2. The visual range under optimal conditions (defined later);

3. The scattering coefficient after suitable data reduction.

1.8.1.1 <u>System components</u> - The system components for field measurement include the following:

1. A 35-mm camera equipped with a 105-mm telephoto lens. The camera must have an automatic exposure control and automatic winder. The automatic exposure feature should not require the light meter to be turned on continuously. (At the present time, a CONTAX is recommended.) The camera must be equipped with the optional data back. Month, day, time of day, and year are the preferred data to be imprinted on the film.

2. Figures 1-4 and 1-5 illustrate a commercially available camera enclosure with its associated installation equipment. Solar panels, not shown, would ensure an extended battery life sufficient for the sampling envisioned in this study. Table 1-9 lists the approximate equipment and supply costs per site.

For the purposes of this protocol, it is assumed that each site will operate during the spring, summer, and fall months when there is not snow on the photographic targets. It is further assumed that one photograph per day will be taken at local noon.

The field technician generally should be able to service the sampling site in one half hour per visit. Since one roll of film will last for 30 days and the sampling season is five months, the total number of manhours per site will be two and a half hours excluding the travel time between the sampling sites and the installation time.

1.8.1.2 <u>Field Procedures</u> - The sampling site should be positioned to photograph north-facing targets, i.e., the camera should point from north to south to provide the best illumination and the least effect from changing sun angles. Wherever possible, the site should be selected with multiple targets i.e., mountains in the field of view with the mountains at different distances from the observing site. Generally, this criterion is difficult to meet. If a choice between views exists, the view selected should be the one closest to the optimal distance from the observing site, which is from one half to two thirds of the average visual range expected.

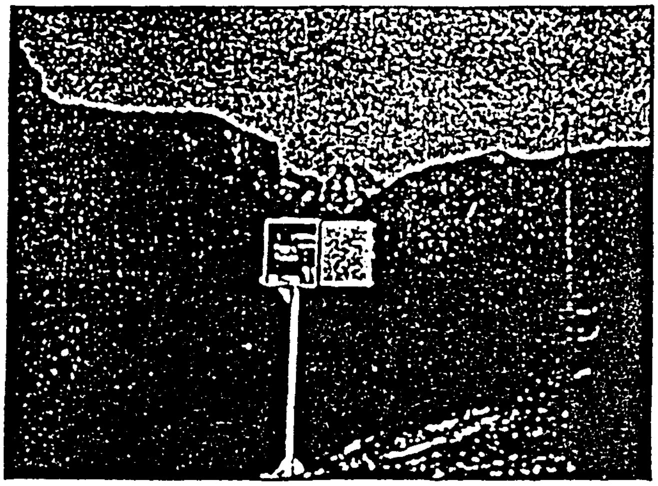

Figure 1-4. Field installation of the enclosure.

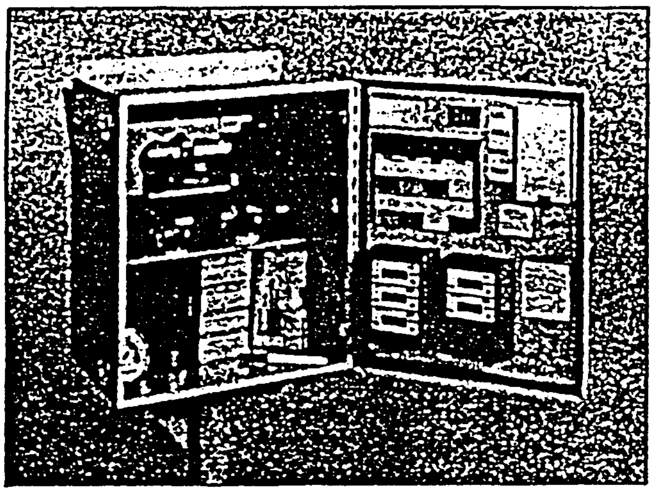

Figure 1-5. A close up view of the enclosure.

Table 1-9.

Approximate Cost of Equipment Per Site

Enclosure complete with batteries, battery charge, and solar power cells	$2,000
Camera with data back, auto winder, and lens	500
Total per site	$2,500
Kodachrome 25 film in 36 exposure rolls with mailers for processing/year/site	$50

Site location. The above criteria dictate that the observing sites should be located in long valleys or on low ridges. The equipment should be removed in the fall and redeployed in the spring. Photographs should be taken from the time the snow leaves the targets in the spring until snowfall in the fall--a different sampling period depending on the climatology of the particular wilderness or other remote area.

Sample frequency. Photographs should be taken daily at noon with the automated camera. When the technician visits the site and changes the film he takes as the first exposure a picture of the color-gray card to supply information necessary for data analysis. After the technician has changed the film, he should check the camera alignment with respect to the scene that is being photographed. A picture of the target is taken at the time of site installation, processed, and included in the shelter for comparison. No other site specific measurements need to be made.

Film handling and storage. The exposed film is mailed in one of the mailers supplied to the technician for processing as soon as possible. The processed film is sent directly to a central processing facility.

1.8.2 Film analysis

The central facility performs all the data processing and analysis. The steps are as follows:

1. The slides are cataloged and assigned serial numbers for storage. The National Park Service catalog procedures, or any other logical system can be used.

2. The slides are projected and classified using the slide classification system developed by SCENES or any other logical system that will separate slides exposed with standard conditions from those exposed with non-standard. Standard conditions are a blue background, no clouds, no snow on target, and no shadows on the site path. These were defined by Allard and Tombach (1981).

1.8.2.1 Data reduction to visual range - Spectral radiance, contrast, and visual range information can be obtained from the photographic slides by suitable reduction techniques. Because of uncertainties in the inherent contrast measurement, the preferred reported variable is the contrast between sky and target and rather than the visual range.

1.8.2.2 Data Base - The data base obtained through these observational procedures can be analyzed for frequency of standard conditions, perception of the scenic values (using the techniques developed by Malm et al. 1981b), and contrast.

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WORK GROUP 2
SOILS AND GEOLOGY

2.1 Purpose

Soils function in the ecosystem in roles that are important to the productivity and diversity of the terrestrial and aquatic biota. In addition, it has a self-contained biota and is an efficient trap or collection system for many atmospheric contaminants. A careful description and a set of quantitative measurements of the soil is essential to estimating the sensitivity or stability of the ecosystem and to determining its response to atmospheric input. The goals of this section are to provide a guide in selecting areas to sample, and to suggest methods for use in the field and laboratory to accomplish the following:

1. characterize the soil-geologic resource, and evaluate its sensitivity to internal change and its ability to buffer the aquatic system; and

2. determine the soils' present condition in terms of pH, nutrient ions, metal load, etc. as a baseline against which to measure future changes.

Two purposes guide the selection of procedures:

1. the information will be used to assist in evaluating the susceptibility or vulnerability of the soils to change due to changes in air quality; and

2. the procedures will be used to monitor the system for evidence of change via repeated measurements.

One important factor that must be considered is response time; while soil and geologic features are quite important influences on the aquatic and terrestrial biological systems, their response to air quality change is likely to be slow and difficult to measure in a time span of a few years.

2.2 List of Measures

The assumed sensitivity of high elevation systems is partially due to the expectation that much of the area may be bare rock, the geologic material is little weathered or perhaps resistant to weathering, and the soils are coarse and shallow, providing little buffer capacity. A reconnaissance survey of the geology is necessary to focus the limited resources for sampling on sites that are most likely to be susceptible to change. The soil physical and chemical properties recommended for measurement here should not be considered limiting. Other measures will be appropriate when the particular area or air source suggests them, but those included in Table 2-1 will be adequate and reasonable in cost for most areas. If advanced analytical techniques for

soil extracts are used, the content of additional metals, for example, might be available at little or no extra cost.

Useful measurements such as bulk density and permeability may be taken where soils contain few stones and allow the extraction of intact volumes with coring devices. Such measurements usually are prohibited by equipment needs or excessive time requirements in most alpine areas. While these additional physical measurements are useful in characterization, they are not of the highest priority since they are not likely to be sensitive indicators of atmospheric changes.

Table 2-1 lists the measures to be used in both the initial characterization and in the periodic sampling. The soil description, mineralogy, particle size analysis, and reconnaissance geologic survey would not be repeated.

Table 2-2 lists the detection levels and precision of the measurements.

2.3 Requirements

Initial characterization of the geology and soils, including writing descriptions, requires the services of two highly trained individuals--a soil scientist and a geologist--both with field experience. Subsequent field sampling of soils can be accomplished by technicians. Approximately one day per site is required for the geologist and soil scientist, assuming the goal is to characterize an area of less than 3 km^3. Subsequent periodic sampling can be accomplished in one day per site.

Field equipment to be transported into the area includes the following:

Soil auger
Sampling tube
Spade
Knife
Topographic maps and aerial photographs
Field pH kit
Soil color book
Notebook
Measuring tape
Polypropylene sample bottles (1 L)
Cloth and plastic bags
Compass
Abney level
Soil coring device with removable rings
Frame, 20 cm X 20 cm
Camera
Ground cloth
Rock hammer

Table 2-1.

Measurements for Characterizing Soils and Geology

Attributes	Methods	Reference No.
Soil description Horizons, Depth, field pH, texture, structure, color, consistence	Pit at plot edge and extent checked by borings	1
Mineralogy	(Mineral soil horizons)	2,2a
sand, silt	Microscopic examination	
clay	X-ray diffraction	
Laboratory analyses		
carbon	Combustion to CO_2	3
LOI (ash)	Wt. after combustion @ 550 C	3
pH	1:1 H_2O and 1.1N KCl	4
exchangeable ions	1N NH_4Ac extract.	5
Ca	Atomic absorption	
Mg	Atomic absorption	
K	Atomic absorption	
Al	Atomic absorption	
Na	Atomic absorption	
Cation exchange capacity	Saturation with Ba repl. with Mg	6
Exchangeable acidity or titratable acidity	BaCl-triethanolamine extract.	7,7a
Percent base saturation	Calculated from measures above	
Extractable SO_4	Water and phosphate extract. ion chromatography	8
Total N in O horizon	Micro-Kjeldahl	9
Total S in O horizon	Leco combustion to SO_2	10
Sulfate retained	Equilibrium with sulfate at 2 and 20 mg/l, ion chromatography	11

Table 2-1. Continued.

Attributes	Methods	Reference No.
Metal content	HCl extractable	12
Pb	Atomic absorption, flameless	
Cd	Atomic absorption, flameless	
Zn	Atomic absorption, flameless	
Ni	Atomic absorption, flameless	
Cu	Atomic absorption, flameless	
Intact soil cores*		
bulk density	volume and mass	2a
pore space	calculated from b.d.	2a
permeability	tempe cell	2a

*Should be taken where soil is relatively stone-free and intact cores can be obtained with reasonable effort with simple cans or coring device.

Table 2-2.

Proposed Detection Limits and Analytical Precision Goals

Attributes	Units	Detection Limits	Precision Goals
Nitrogen	g/kg	1.0	5%
Carbon	g/kg	1.0	5%
Loss on ignition	g/kg	1.0	5%
pH	pH units	---	$\pm$0.1
Exch. calcium	cmole/kg	0.02	5%
Exch. magnesium	cmole/kg	0.02	5%
Exch. potassium	cmole/kg	0.02	5%
Exch. aluminum	cmole/kg	0.02	5%
Exch. sodium	cmole/kg	0.02	5%
Cation exch. cap.	cmole(+)/kg	0.1	5%
Exch. acidity	cmole/kg	0.1	5%
Sulfate	mg/kg	0.5	5%
Sulfur	mg/kg	0.5	5%
Lead	mg/kg	0.1	5%
Cadmium	mg/kg	0.1	5%
Zinc	mg/kg	0.1	5%
Nickel	mg/kg	0.1	5%
Copper	mg/kg	0.1	5%
Other metals	mg/kg	0.1	5%
Bulk density	g/cm^2	0.1	5%
Pore space	ml/ml	0.01	5%
Permeability	cm/hr	0.1	5%

All equipment needed for the soil and geologic characterization and sampling is transportable on one pack animal.

2.4 Field Procedure

2.4.1 Site Selection Process and Geologic Characterization

The site selection process will be the responsibility of the land manager and quite specific for each region. We suggest a hierarchical approach working from very large land areas, such as the entire wilderness area, down to selecting the landscape units (small watersheds, for example) that will be characterized and sampled. All of the available information from numerous disciplines should be integrated in the landscape unit selection process. Information on geology, soils, aquatics, vegetation, and general knowledge of the area, including public concerns and proximity to known or potential contamination sources, will be useful.

After landscape units are selected, plots, lakes, and streams are selected for more intensive characterization and long-term monitoring. Each watershed or landscape unit selected is mapped for bedrock and surficial geology on a reconnaissance scale. The soils are mapped at the same scale and differentiated at family or subgroup level or mapped by soil associations if recognized soil series are available. Since these mapping procedures are somewhat subjective and require a trained scientist following established procedures common to the discipline, they are not be included here.

2.4.2 Sampling Strategy

Conceptually, a few carefully chosen plots can be considered representative of sensitive areas even though they may not be truly representative of the entire area of concern. A few plots thoroughly characterized for soil and vegetative properties can be monitored for change more easily and result in higher probability of detecting adverse impact than a sampling scheme directed at whole watersheds or whole wilderness areas.

Selection of plots begins with a map survey (using aerial photographs) and the selection of specific landscape units thought to be the most sensitive. The sampling plots themselves should be representative of major soil-geologic-vegetative types within the landscape unit chosen. Whenever possible, the sample plots should be coordinated with those for aquatics and vegetation. In addition, the choice of location should also consider proximity to sources, public concerns, and area coverage.

2.4.2.1 Location of plots - Due to size, diversity, and spatial variability, permanent plots will be established in selected geology-soil-vegetation associations within major watersheds surrounding lakes and/or streams that are being sampled. This strategy will provide the opportunity for more

precise characterization of small, representative segments of the area under study rather than attempting to characterize baseline conditions throughout the area. Because of the lack of any prior classification scheme in which "associations" in these regions are recognized, on-the-spot classifications and descriptions will usually be necessary.

2.4.2.2 Size of plots - Alpine mosaics, whether recognized as patches or as changes along gradients, are usually finer grained than even a tenth of a hectare. Therefore, plots will by necessity often include more than one vegetation "type" in order to provide adequate size for repeated sampling without destruction of the site. Although some flexibility in size is necessary to accommodate differences in fineness and complexity of the soils-geologic-vegetative types, we recommend a target size of 1000 m^2.

2.4.3 Sample Location, Number, and Frequency

The reconnaissance geologic survey maps and aerial photographs will be used on site to select plots for detailed characterization. These plots will be limited in number, depending on the size and complexity of the watershed or other geologic unit selected. The plots should be the same as those used in the vegetation studies. Plots should be permanently marked at four corners with flush markers located on photographs by reference to prominent landmarks.

For the initial characterization, a single soil pit is dug at the edge of the plot for detailed descriptions and the collection of samples, horizon by horizon, to a depth of 1.5 meters or to a limiting layer. Borings which minimize disturbance are taken around the periphery of the plot to ensure that the pit is representative of most of the soil over the plot.

Because one goal is to measure temporal trends, the emphasis is on surface soil samples. Deep samples are needed for complete characterization of the site. Within each permanent plot, 12 samples each of the O horizon(s), if present, and top 2 cm of surface mineral horizon are taken at each sample interval.

Samples taken to detect changes should be collected on a five to ten year cycle. More frequent sampling is unlikely to show changes even in severely contaminated areas.

2.4.4 Sample Collection Procedure

Samples should be tested for pH immediately in the field by the dye technique (Table 2-1). Organic horizons can be placed directly into bottles or plastic bags after separation of the mineral soil. The O horizon samples should be collected from within a known surface area by cutting around the inside of a 20 cm X 20 cm frame. Moist mineral soil samples gently crushed and passed through a 2 mm stainless steel screen should be placed in 1 L polypropylene bottles for transport. Bottles should be

permanently numbered. A record of bottle number, sample location, depth, date, and remarks should be kept and as much information as possible also recorded on the bottles. An estimate of percentage of material above 2 mm (that screened out) should be recorded. Samples of the coarse material should be taken in cloth bags for mineralogical analysis. Initial samples taken from the pit should include undisturbed core samples, representative of each horizon, for bulk density, pore space, and permeability tests.

2.4.5 Field Storage and Handling

Soil samples for pH, extractable sulfate and nitrogen should be maintained moist and cool as possible until they reach the laboratory, where the sample can be split. An aliquot for the above analyses is stored at 4^{o} C and the remainder is air-dried for physical and chemical analysis. Air-dried samples can be stored indefinitely at room temperature.

2.4.6 Hydrologic Sampling

In remote areas, the sampling of springs and seeps offers the best approach to sampling soil water. Sites are permanently marked for sequential sampling and subjected to analyses prescribed for lakes and streams. Alternatively, tube lysimeters could be installed for periodic sampling if groundwater measurements are essential, but the procedures are not described here.

2.5 Laboratory Analysis

Only the initial samples will be subjected to bulk density, permeability, mineralogical, and textural classification.

The characterization samples and the surface horizons collected repeatedly should be analyzed for the chemical properties shown in Table 2-1. The methods to be used are found in the references cited in Table 2-1 and listed in Table 2-3.

2.6 Support Needs

The vegetation sampling and soil sampling must be closely coordinated. The soil sampling should support the vegetation analyses and the aquatic characterization; therefore, the locations must be coordinated.

Table 2-3.

References for Analytical Techniques

Reference No.	Citation
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2a	Black, C.A. 1965. Methods of Soil Analysis, Part 1. ASA Monograph No. 9, American Soc. Agronomy, Madison, WI. pp. 545-566, 604-630.
3	Page, A.L., R.H. Miller, and D.R. Keeney. 1982. Methods of Soil Analysis, Part 2. ASA Monograph No. 9 (2nd ed.), American Soc. Agronomy, Madison, WI. pp. 539-552. (Also see Robarge and Fernandez, pp. 179-180.)
4	Page, A.L., R.H. Miller, and D.R. Keeney. 1982. pp. 208-209. Robarge, W.P. and I. Fernandez. 1986. pp. 130-134.
5	Robarge, W.P. and I. Fernandez. 1986. pp. 130-140. Page, A.L., R.H. Miller, and D.R. Keeney. 1982. pp. 159-164.
6	Page, A.L., R.H. Miller, and D.R. Keeney. 1982. pp. 149-157.
7	Page, A.L., R.H. Miller, and D.R. Keeney. 1982. pp. 159-164.
7a	Robarge, W.P. and I. Fernandez. 1986. pp. 141-148.
8	Robarge, W.P. and I. Fernandez. 1986. pp. 159-164. Johnson, D.W. and G.S. Henderson. 1979. Sulfate adsorption and sulfur fractions in a highly weathered soil under a mixed deciduous forest. Soil Sci. 128:34-40.
9	Page, A.L., R.H. Miller, and D.R. Keeney. 1982. pp. 595-622.
10	Page, A.L., R.H. Miller, and D.R. Keeney. 1982. pp. 501-534. Robarge, W.P. and I. Fernandez. 1986. pp. 130-134.

Table 2-3. Continued.

Reference No.	Citation
11	Johnson, D.W. and G.S. Henderson. 1979. Robarge, W.P. and I. Fernandez. 1986. Blume, L.J. 1985. Statement of Work, National Acid Deposition Soil Survey. Chemical and Physical Characteristics of Soils. IFB No WA 85-566 EMSL, U.S. EPA, Las Vegas, NV.
12	Robarge, W.P. and I. Fernandez. 1986. pp. 149-153. Page, A.L., R.H. Miller, and D.R. Keeney. 1982. pp. 323-334, 347-362.

WORK GROUP 3
AQUATIC CHEMISTRY

3.1 Purpose

The objective of this protocol is to provide guidance for determining baseline chemical characteristics of surface waters in alpine and subalpine wilderness areas. The proposed protocols are essentially limited to sample acquisition, stabilization, and analysis.

Although these design issues cannot be pre-specified, in general we recommend a two-stage strategy for determination of baseline chemical characteristics of surface waters. Stage I would determine the presence and spatial distribution of sensitive surface water systems. The level of effort required at Stage I will be dependent upon the amount of existing information. Stage II would then involve the selection of sensitive system(s) for more intensive study and longer-term monitoring. If information on historical rates of deposition is required, sediment coring could be a component of Stage II, and would require additional protocols.

The following protocol is proposed as a practical approach to obtaining an initial characterization of baseline chemistry of lakes and streams in remote high-elevation wilderness areas. In conjunction with a sampling design appropriate to local conditions, these attributes and this sampling and analysis methodology should meet a Stage I objective of establishing the range and distribution of chemically differing aquatic systems. A sufficiently reliable basis would be provided for establishing classes of aquatic systems according to sensitivity of response types. Depending upon further definition of objectives, a more rigorous sampling and analysis protocol could be implemented for the Stage II sampling program directed toward identification of temporal variation and trends.

3.2 List of Measures

3.2.1 Major Ions in Water (including Al)

Table 3-1 provides a general list of measurements important for characterizing existing surface water composition. The list includes the major mineral species commonly present in low ionic strength surface waters, and the basic parameters associated with nutrient status and biological productivity. The list of measurements may be considered optimal, though not all inclusive, depending upon case-specific conditions. Some constituents, including aluminum fractions, dissolved organic carbon, fluoride, and ammonium, are commonly present at very low concentrations. After confirmation of low concentrations, these measurements could be deleted, or obtained on a less frequent basis than other constituents. Dissolved oxygen and transparency measurements would only be obtained when mid-lake sampling is conducted.

Table 3-1 also lists the recommended methods of sample analysis. Accuracy and precision goals (NSWS 1986) are listed in Table 3-2. Sample container and preservation requirements are listed in Table 3-3. Sample holding times are listed in Table 3-4. Specific analytical procedures are provided by reference to the National Surface Water Survey (NSWS 1986), a regional-scale survey of stream and lake chemistry conducted by the U.S. EPA. The NSWS provides the most credible and well-documented protocol for determination of chemistry in natural, low ionic strength waters. This project includes a Western Lake Survey conducted in cooperation with the Forest Service. The results of this work should provide an improved perspective on sampling and analysis methods as well as on the degree of precision and accuracy attainable. Of specific interest is the comparative study of pH measurements, including the development and use of a closed system pH determination. Preliminary results favor this method based on precision and accuracy levels. Inclusion of this method in the proposed protocol would eliminate the need for <u>in situ</u> pH determinations, which would greatly expedite the sample collection process. The NSWS is ongoing, with important methodological findings still emerging. The methods proposed may not fully reflect the current information status; the proposed protocol should be considered tentative and subject to modification as results of the NSWS and other current studies supporting methods assessment become available.

3.2.2 <u>Trace Metals in Sediments</u>

Trace metals in sediments can provide historical deposition records. Studies in Rocky Mountain National Park and in the Wind River Range indicate a history of atmospheric input of some heavy metals (most notably Pb) over a ± 100-year period. Collecting this record is a viable research goal to determine the history of the input of atmospheric pollutants that are <u>preserved</u> (not necessarily in proportion to atmospheric flux) in lake <u>sediment</u> or peat. (There are probably few ombrotrophic bogs suitable for such studies.)

Briefly, we suggest the following in conjunction with Stage II sampling if information is needed on historical deposition rates.

1. Coring of lake sediment from selected lakes.

2. Abbreviated analysis of sediments to establish approximate chronology and compare pre-1800 to modern chemical-biological characteristics.

   Sample intervals: 1-2, 5-6, 10-11, 15-16, 20-21, 25-26, 30-31, 35-36, 40-41 cm.

   Chemical parameters: ^{210}Pb activity, H_2O and organic content, major metals (Cd, Mg, K, Na, Al, Fe, Mn), trace metals (Pb, Zn, Cd, Cu, B), polycyclic aromatic hydrocarbons, charcoal, and soot.

Table 3-1.

Measurements Required for Characterizing Baseline Water Quality

Attributes	Methods
Alkalinity	Gran's method
Aluminum (labile and total)	Atomic absorption spectrophotometry (graphite furnace)
Ammonium	Standard indophenol blue technique
Calcium	Atomic absorption spectrophotometry or ICP
Chloride	Ion chromatography
Chlorophyll a*	Methanol extraction/fluorescence
Dissolved organic carbon	Infrared spectrophotometry
Fluoride	Ion-selective electrode and meter
Magnesium	Atomic absorption spectrophotometry or ICP
Nitrate	Ion chromatography
pH	pH electrode with expanded-range pH meter (closed system)
Phosphate	Standard molybdenum blue technique
Potassium	Atomic absorption spectrophotometry
Silica	Standard molybdenum blue technique or ICP
Sodium	Atomic absorption spectrophotometry
Sulfate	Ion chromatography
Conductance	Conductivity cell and meter
Dissolved oxygen	Dissolved-oxygen meter
Transparency	Secchi disk

*Chlorophyll a determinations are included to support the aquatic biology protocol in the following section.

Table 3-2.

Proposed Detection Limits and Analytical Precision and Accuracy

Attributes	Units	Detection Limits	Relative Standard Deviation*	Accuracy Maximum Bias
Alkalinity	ueq/l	5	10%	10%
Aluminum, total	mg/l	0.005	20%	20%
Aluminum, extractable	mg/l	0.005	20%	20%
Ammonium	mg/l	0.01	5%	10%
Calcium	mg/l	0.01	5%	10%
Chloride	mg/l	0.01	5%	10%
Chlorophyll a**	ug/l	0.02	5%	10%
Dissolved organic carbon	mg/l	0.1	10%	10%
Dissolved oxygen	mg/l	-	5%	5%
Fluoride	mg/l	0.005	5%	10%
Magnesium	mg/l	0.01	5%	10%
Nitrate	mg/l	0.005	10%	10%
pH				
Field	pH units	-	-	-
Lab	pH units	-	-	±0.1 pH
Phosphate, total dissolved	mg/l	0.002	20%	20%
Potassium	mg/l	0.01	5%	10%
Silica	mg/l	0.05	5%	10%
Sodium	mg/l	0.01	5%	10%
Sulfate	mg/l	0.05	5%	10%
Conductance	uS/cm	-	1%	5%

*RSD at concentrations 10X above detection limits.
**Chlorophyll a determinations are included to support the aquatic biology protocol in the following section.

Table 3-3.

Recommended Sampling Aliquots, Containers and Preservation

Container:	1 (1000 ml) LDPE bottle	2 (125 ml) LDPE bottle	3 sealed 60-ml syringe	4 sealed 60-ml syringe
Preservative:	Kept cold in dark	pH < 2 with H_2SO_4	Kept cold in dark	Kept cold in dark
	VARIABLES			
	Al	DOC	pH^3	Al^1
	F	NH_4		
	SO_4			
	NO_3^-			
	SiO_2			
	Ca			
	Mg			
	K			
	Na			
	Total P			
	Total Al			
	Al^2			
	Alkalinity			
	Spec. conductance			
	pH^2			

NOTE: As stated in text, concentrations of DOC, Al, and NH_4 are usually low and may not require routine analysis. In that case, only two aliquots, (1) and (3), would be collected.

pH^2= laboratory pH, open system measurement, obtained at lab temperature with an open system.

pH^3= closed system pH.

Al^1= laboratory extraction of closed system sample for organic and inorganic fractions.

Al2= total Al.

Chlorophyll a: See Holm-Hansen and Riemann (1978).

Table 3-4.

Analysis Time Frame

On site	Same day	One week	Four weeks
pH^1	pH^2	pH^3	SO_4
DO		Al^1	NO_3*
		DOC	SiO_2
		NO_3	Al^2
		Specific conductance	NH_4
			Ca
			Mg
			Na
			K
			F
			Total P
			Alkalinity

pH Options:

1. *In situ* pH, open system measurement obtained at field temperature.
2. Laboratory pH, open system measurement, obtained at lab temperature.
3. Closed system pH.

Al^1 Laboratory extraction of closed system sample for organic and inorganic fractions.

Al^2 Total Al.

NO_3* The NSWS holding time is 1 week, but some evidence indicates stability for 2-4 weeks if maintained at 4° C in the dark.

Chlorophyll a: Maximum of three weeks - see Holm-Hansen and Riemann (1978).

Biological parameters: diatoms, chrysophytes, and pollen.

It will also be possible to evaluate the flux of anthropogenic material (atmospheric pollutants) to the sediments.

Coring of the lake sediment is a difficult operation to perform. It is even more difficult given the constraints imposed in wilderness areas. If sediment coring is deemed necessary, a well-developed protocol will be necessary.

3.2.3 Trace Metals in Water

We recommend that only labile and total aluminum be determined in the surveys because of the following:

1. Aluminum is biologically important,

2. Aluminum is very sensitive to changes in pH, and

3. Natural levels can be measured with fair precision and accuracy.

We do not recommend that other metals be measured because of the following:

1. None have been identified as having effects on biotic systems at natural levels,

2. Natural variability is high and therefore trends will be difficult to discern, and

3. Trace metals are difficult (and expensive) to collect and analyze at natural levels.

3.3 Requirements

3.3.1 Manpower

The level of effort required to collect the recommended samples has two components: 1) traveling to the sampling site, and 2) sampling the water and sediment. The amount of time required to get to the sampling sites will be site specific and cannot be prescribed except to say that enough travel time should be allocated so that field operators can perform careful work at the sampling site.

The amount of time required to take the water samples is approximately 0.5 days, although individual sites may require longer. To take sediment cores, an additional 0.5 - 1 day is necessary.

3.3.2 Equipment

Backpacks
Sampling containers for each location: 1 1000-ml LDPE (low density polyethylene) bottle, 1 125-ml LDPE bottle, and 2 60-ml syringes
pH and conductivity meters
Ice and coolers for samples
Raft when taking mid-lake samples
Van Dorn bottle, dissolved oxygen meter and Secchi disk when taking mid-lake samples

3.4 Field Procedures

3.4.1 Sampling Strategy

Stage I in a two-stage sampling strategy would be conducted to determine the distribution of sensitive lake and stream systems. The level of effort required at this stage will depend upon the value of existing data. Existing data would be adequate if determined sufficient to identify the most sensitive landscape units and place the watersheds in sensitivity classes. Synoptic survey data should be obtained that reflect the spatial scale and distribution of response controlling landscapes. Records of existing surface water chemistry, as well as maps of surficial materials (soils and geology) and vegetation, should be employed in identifying landscape units and in determining additional data collection needs. Even where surface waters can be lumped into general sensitivity classifications, a more detailed survey focused on individual classes may be useful for identifying the most sensitive class members.

Stage II would require selection of the most sensitive class, or classes of lakes and streams, for monitoring and more intensive study. Ideally, one small, well-defined watershed would provide an excellent study area for measurements of aquatic chemistry and biology, and also vegetation and soils. These measurements are easier to perform, interpret, and subsequently monitor when they are made within the same known watershed.

3.4.2 Location of Sampling Sites at Lakes and Streams

If mid-lake samples are to be taken, lakes should be sampled 1.5 meters below their surface in the middle of the lake. Samples of the outlet and a major inlet also should be sampled at a location with appreciable water flow (i.e., no stagnant pools).

Streams should be sampled at mid-stream and mid-depth in areas of appreciable flow.

3.4.3 Number of Water Samples and Frequency of Sampling

Two to four aliquots should be taken at each site depending upon the suite of analyses. Each aliquot has its own preservation and treatment protocol (Table 3-3). This sampling

protocol generally is adopted from the NSWS (1986). Our protocol differs from the NSWS protocol in that it does not recommend filtering (because of contamination problems and the lack of large amounts of suspended particulates in the high elevation surface waters) and sampling treatment is minimized.

Ten percent of all sampling and analysis should be done in triplicate to provide an indication of the uncertainty associated with the sampling and analysis procedures. Additional quality assurance protocols should be used as described in the NSWS plan (1986). At a minimum, quality assurance should include analysis of sampling replicates, blanks, and NBS traceable reference standards.

Sample frequency should include 3-4 samples annually taken between early spring and early autumn. The exact date of the first sample will depend upon field conditions.

3.4.4 Water Sample Collection Procedures

The lake and stream water sampling procedures of the NSWS (1986) should be used. In general, lake and stream samples should be collected with LDPE sampling containers that have been acid-washed (HNO_3) and copiously rinsed with deionized water. At the sampling site, the bottles and the caps should be rinsed 3 times with the lake or stream water before taking the sample. The syringes should be rinsed three times prior to sample collection. Samples should be placed on ice immediately after collection.

3.4.5 Field Measurements

We recommend that specific conductance measurements be taken each time samples are collected. Dissolved oxygen and transparency would be measured on site when mid-lake sampling is conducted. *In situ* pH measurement (pH^1 in Table 3-1) can be taken if the closed system measurement (pH^3) method is not used. We recommend closed system pH measurement because of the low precision associated with *in situ* open system measurements. If *in situ* pH^1 is measured in lieu of the closed system pH^3, we recommend that an open system lab measurement (pH^2) also be made.

3.4.6 Water Sample Storage and Transport

Immediately after collection, the samples should be packed in an insulated container with a refrigerant and thereafter maintained in the dark at approximately 4° C until analyzed.

3.5 Laboratory Sample Analyses

The water samples will be analyzed for constituents by the methods listed in Table 3-1. These methods are described by the NSWS (1986). The appropriate units of measure are listed in Table 3-2.

3.6 Support Needs

No biological measurements are required to support the chemical measurements.

In addition to the physical measurements already mentioned (e.g., transparency), additional physical measurements are water temperature and, in the case of streams, water flow.

3.7 Data Analysis

Data analysis that would be required in addition to standard statistical analyses to determine data quality, depend completely on the objective of the study and cannot be prescribed.

AQUATIC BIOLOGY

3.8 Purpose

The primary objective of monitoring aquatic biota in wilderness areas is to provide information on the status of sensitive biological communities over time from which can be derived inferences of man-induced change or lack of change. This general goal must be considered within the context of limited monitoring resources (constraints of time, money, access to sampling sites, etc.) which, for example, preclude the study of seasonal biological dynamics. Cause-and-effect relationships between anthropogenic disturbances and biological responses also cannot be delineated (except for catastrophic change) in complex ecological systems by monitoring alone. Moreover, the sensitivities of specific aquatic biota to different anthropogenic stresses generally are poorly known in subalpine and alpine regions. Consequently, the monitoring activities described here represent our best approximation of a minimal array of sensitive components that if monitored with reasonable intensity and frequency will provide an estimate of the health of aquatic communities in remote wilderness regions. Although sampling error undoubtedly will be high (i.e., high variance among replicate and time series data), we have little alternative to accepting high error short of simple presence/absence surveys or no monitoring at all. Although present monitoring methods may be crude, it is obvious that the alternatives are undesirable from a resource management perspective.

The biological components that constitute a minimal set for detecting change in alpine and subalpine waters are Chlorophyll a, salmonid fisheries, and macroinvertebrates. Chlorophyll a (Tables 3-1 and 3-2) is the best readily measurable attribute of phytoplankton biomass (primary producers) related to the trophic status of surface waters, which may be stimulated (fertilized) or reduced by atmospheric deposition. Macroinvertebrates and salmonid fish are sensitive to many types of anthropogenic disturbances; are not typically ephemeral in a given lake or stream (although specific life-cycle periods are ephemeral); can be quantitatively monitored by routine field practices; and in the case of fish, are highly valued components of wilderness surface waters.

Monitoring of other aspects of lower trophic levels (such as phytoplankton and zooplankton community structure) presently are not as reliable indicators of change because

1) they have high natural variability, both seasonally and year-to-year;

2) we do not understand what complex factors drive the shifts in community structure or biomass during early stages of anthropogenic disturbance (e.g., lake and stream acidification); and

3) they have low or unknown sensitivity to change during early stages of anthropogenic disturbance.

As previously noted, these protocols are not intended to be research directives. However, we recognize that remote sensing of the trophic status of wilderness lakes has great potential and that amphibians, especially salamanders, may prove to be important indicators of biological change. Because these monitoring approaches for alpine and subalpine regions are in the developmental stage, they have not been discussed here.

3.9 Salmonid Fish

The following protocol is based upon limitations of access, time, manpower, and transport of equipment inherent in sampling of high-elevation lakes in remote wilderness regions. Such limitations dictate that only a small set of basic data be collected to characterize fish stocks. Further assumptions used to develop this protocol are described in the following paragraphs.

The general objective of this protocol is to correlate independent fishery variables to changes in surface water quality. However, quantitative assessment of fishery stocks in remote lakes for long-term trend analysis is not well developed. Most monitoring of high-elevation fisheries in the Rocky Mountains has been biased toward general management goals that do not require a high degree of accuracy or precision of technique. For example, the efficiency of sampling effort using specific gear is a function of fish species, standing stock, seasonal behavior, habitat, and morphometric features of lakes and is not quantified for high-elevation salmonid fisheries. Little guidance on the quantification of alpine salmonid fish stocks can be derived from existing data. Consequently, collection of unbiased fishery data in wilderness lakes is unlikely (Thornton et al. 1986).

Because the availability of sampling gear at each lake will be limited, sampling for target fish species will be emphasized. This may preclude complete characterization of the fish community in some lakes. However, most alpine and subalpine lakes in the Rocky Mountain region did not historically contain fish and existing fish populations have been established by stocking. Therefore, most high-altitude fisheries in the Rocky Mountain Region contain only one or two species of introduced salmonids. For example, only a few Cutthroat populations were found historically in the high-elevation lakes of the Wind River Mountains in Wyoming. Other fish species associated with oligotrophic conditions are not commonly found. For example, sculpins, suckers, and dace are not found in high-elevation lakes in Wyoming due to high gradient streams, although sculpins are occasionally found in mid-elevation lakes. Speckled dace and

long-nose suckers are found in some alpine lakes in Colorado but their occurrence is not common; both of these species have probably been introduced. The alpine lakes in Colorado containing fish species other than salmonids probably number less than one hundred (W. Nelson, Colorado Division of Fish and Wildlife, personal communication).

The lakes selected for long-term monitoring should, as possible, also be used for chemical monitoring (see aquatic chemistry section). However, monitored lakes must be capable of sustaining fisheries over periods of many years (e.g., probability of winter kill must be low) and the lakes must not exhibit a high degree of heterogeneity of fish habitat (e.g., selected lakes should be relatively circular and not contain coves) which tend to develop sub-populations of fish. Lake morphometry should be relatively uniform as is conducive to random dispersal of active fish populations. Harvest by angling should be insignificant compared to natural sources of mortality and be relatively constant year to year. The potential for over-harvesting by fishermen must be considered during lake selection.

Ideally, lake fisheries that are monitored should be sustained by natural reproduction because early life stages of salmonids are very sensitive to changes in water quality. This may be an impractical constraint, however, because many lake fisheries in alpine wilderness regions are maintained by periodic stocking. In addition, the availability of spawning habitat has been found to be positively correlated with population strength and size of individual fish in wilderness lakes (Hudson et al., 1980).

Salmonid fisheries are assumed to be of primary interest. Such fisheries are to be sampled once during a sampling year over a 2-3 day period using equipment that can be transported by horse or backpack only. The field crew should consist of 2-3 individuals with use of an inflatable raft. A requirement for non-destructive sampling in wilderness lakes will be adhered to as much as possible but complete elimination of sampling mortality is difficult.

Experience has shown that absolute measures of fish stocks are difficult and time consuming to acquire in the alpine (e.g., mark-recapture techniques require at least one week of sampling). Thus, the specific objectives here are to quantify relative indices of fishery status. These include (beyond presence of a specific fishery) the following:

- catch per unit effort (CPUE),
- population age structure,
- condition factors,
- growth and mortality rates, and
- absence of year classes or weak year classes.

3.9.1 Field Sampling

3.9.1.1 Sampling Design - Collection of representative, random samples of individuals from a fish stock optimally should be based on a stratified random sampling design where strata represent different habitat types. In alpine lakes that have restricted sampling area (due to steep morphometry, boulder fields, or other morphometric features), site-specific judgement on net placement may be based on experience with collecting mobile salmonids if experience dictates that a representative sample of fish from the total stock will be collected.

3.9.1.2 Sampling Frequency - It is generally recommended that the frequency of fish sampling be related to the potential rate of change of surface water chemistry (Lambrou et al. 1985). For intensively-monitored lakes where close observation of fishery status is desired in the event that such lakes undergo rapid change (e.g., dilute headwater lakes), fish sampling should be performed at one- to two-year intervals. For lakes not expected to exhibit rapid chemical change (e.g., larger or less dilute subalpine lakes), fish sampling should be conducted at three- to four-year intervals (Lambrou et al. 1985). During a given sampling year, sampling should be conducted once during mid to late summer so that young-of-year may be observed. This time will vary from late July to late August depending upon whether fall or spring spawning species are present.

3.9.1.3 Sampling Intensity - Sampling intensity should involve both minimal sampling effort and minimal sample sizes. Minimal sampling effort should be expended at each monitored lake according to the recommended number of net sets for lakes of given sizes (see below). Minimal sample size should be collected according to the following protocols.

Total fish collected for each monitored species should be 100-150 with 150 being preferred. Some field experience, however, suggests that as few as 30 captured individuals may be adequate to characterize fisheries with limited stock size (Remmick, 1984). Other recommendations include sampling at least 10 fish per 2 cm size length over the size range of maximum accuracy for individual fish statistics (see discussion below). Lambrou et al. (1985) recommend that at least 60 fish evenly distributed across size classes be measured for developing fishery statistics (see also Thornton et al., 1986).

It should also be noted that stressed fish populations contain the fewest individuals and require the greatest effort to achieve population estimates of known variance.

3.9.2 Field Procedures

3.9.2.1 Sampling Gear - Because collecting unbiased fishery data is difficult, more than one type of sampling gear should be used. However, experience has shown that monofilament gill nets are effective in collecting most fish species found in remote Rocky Mountain lakes (e.g., Hudelson et al. 1980) and are easily transported. Trap nets are presently being designed that are more portable than previously available (e.g., modified Alaska trap net; ALSC 1985). Such nets may become useful in the future to supplement gill netting, although portable trap nets did not prove effective for surveying fish stocks in small Maine lakes (Haines et al. 1985).

Swedish gill nets (standard 150 ft length, 6 ft depth with 5 panels of 1/2, 3/4, 1, 1 1/2 inch bar mesh) should be used because they are especially effective in capturing mobile salmonid species. These nets are capable of capturing fish as small as 7-8 cm total length. Thus, the gill netting should be effective on age I fish and older but should not be effective on young-of-year (y-o-y).

3.9.2.2 Net Placement - Trend analysis of fishery status based upon results of gill netting will only be as reliable as the reproducibility of sampling technique for each monitored lake. Location of nets, orientation along the bottom in relation to shoreline, diel time of placement and collection, and season of placement must be standardized for each lake. Because lake sampling programs will be site specific, standardization must be within a given lake and not between lakes.

Nets placed in a similar manner and time each sampling year give reasonably comparable estimates of population characteristics (Hubert 1983). Close adherence to standard collection procedures for each lake will minimize total variance in catch statistics due to unknown or uncontrollable biotic and abiotic factors.

Each lake has a unique morphometry and net placement must be carefully considered according to lake characteristics and target species. Generally, gill nets set along the bottom in shallow waters not exceeding 5-7 m depth will capture a representative sample of the total fish stock if crepuscular activity periods are sampled. Salmonids in alpine lakes in the Rocky Mountain region are typically found in relatively shallow waters and in general are closely associated with the benthos as the primary food resource (e.g., Golden trout are found in close proximity to sediment). Nets should be placed perpendicular to the shoreline in shallow water or at 45° angles in deep water, with the small mesh nearest shoreline. If the initial sampling effort yields few or no fish, the sampling stations should be moved and the sampling effort repeated.

A rough guideline for number of nets to use is as follows:

Lake size	Number of 150 ft Swedish gill nets required
Less than 10 acres	1
10-25 acres	2
25-50 acres	3
50-100 acres	4
Each additional 100 acres	add 1 net

However, three gill nets set in different habitat may be the maximum number effectively operated by a field crew of 2-3 persons.

As previously noted, sampling mortality associated with gill netting should be avoided in wilderness lakes, especially in those with relatively small fish populations. Overnight sets where the dusk (one hour before sunset) and dawn (one hour after sunrise) activity periods are bracketed generally will capture a representative sample of fish. However, such long sets may produce mortalities above 50% in capture fish. Thus, gill nets should be deployed by midday in high-elevation lakes where foraging by salmonids is more or less continuous. These nets should be tended every 1 1/2 to 2 hours to minimize capture mortality. The nets should be run until after dusk to bracket one crepuscular activity period. If fishery stock is abundant, and some sampling mortality is acceptable, one net set over night may be useful to sample larger, night-feeding individuals.

3.9.2.3 Fish Processing - Handling time of fish should be minimized once fish are removed from the net. Fish should be kept in a live-car attached to the side of the raft during handling and be released as soon after capture and measurement as possible. Handling mortality should be recorded if observed. Procedures for reducing handling mortality have been reviewed by Stickney (1983).

Fish collected should be carefully removed from the gill net (using a small polished hook to minimize damage to fish and technician), identified to species, measured to nearest mm, weighed to nearest gm (by volume displacement for fish less than 50 gm and by spring scale for fish greater than 50 gm), and scale samples taken (on left side just posterior to and below dorsal fin and above the lateral line).

3.9.2.4 Recording of Field Data - Field data recording should be standardized and include the following:

- lake;
- sampling date;
- gear type;
- net location, shoreline orientation, depth, placement time, and collection intervals;

- species, weight (gm), total length (cm), and location of scale collection site for each individual fish collected;
- observations of parasites, wounds, deformities, or other abnormalities; and
- capture mortality and injury.

Lake temperature at sampling location and other pertinent chemical condition information such as dissolved oxygen or pH is useful to record on field sheets if available.

3.9.2.5 Additional Fish Surveys - A reconnaissance-level, qualitative assessment of reproductive success can be made by looking for juvenile fish in shallow habitat and in shoreline cover. Small hand seines and dip nets may be used to find young-of-year but success may be limited. Small baited hardware cloth minnow traps have not proved effective in capturing young-of-year salmonids (T. Haines, personal communication). Alternatively, trapping of drifting fry in outlet streams during sampling for macroinvertebrate drift may be possible.

3.9.3 Laboratory Procedures

Fish stocks in unproductive high-elevation lakes generally exhibit very slow growth rates in the older age classes due to food limitation. Generally, rapid growth occurs in such lakes only to approximately 20-25 cm in total length. Thus, older fish are more difficult to age accurately by scale readings. Obtaining accurate weights in the field on fish smaller than 12-15 cm also is difficult due to variations in water content and from wind effects on weighing devices. Additionallny, the more numerous individuals in the younger age classes place large demands on a lake ecosystem to provide habitat and food. Therefore, it is appropriate to obtain weight-length measurements for all fish captured, unless sub-sampling is required due to large numbers of individuals captured. But fish in the 12-25 cm total length range only should be used to determine the population parameters discussed below.

It should be noted that use of scales to age individuals from wild salmonid populations during the early rapid growth phases of ages I-IV is the most accurate, non-destructive technique available for aging. However, aging by scale analysis is not as accurate for stocked fish due to possible interruption of growth in the period immediately following stocking. Stocking may produce a growth check similar to an annulus. Fall spawning species such as Lake trout produce a better annulus during age 0 in comparison to late spring spawning species such as Cutthroat and Golden trout, which sometimes do not get a good scale growth before the first winter producing an indistinct first annulus.

Careful training of technicians should be done using scales from the monitored species that are from fish of known age and comparable growth environment. Random recounting of approximately 5% of fish scales by a second trained technician is

appropriate as a quality assurance check. An 80-90% comparison of scale readings between two technicians typically is good (Thornton et al. 1986).

3.9.4 Supporting Data

As noted above, the fisheries monitored should be in lakes whose water chemistry is also being monitored. Better resolution of ongoing environmental change or stability will result from such integrated studies.

3.9.5 Data Analysis

3.9.5.1 Catch Per Unit Effort (CPUE) - Catch per unit effort is a relative measure of population strength. Theoretically, it should be linearly proportional to the abundance of fish stock: catch = capture efficiency x fishing effort x fish abundance. However, capture by passive fishing techniques is a function of fish movement and consequently CPUE is not dependent fully on stock size (Hubert 1983), and CPUE has frequently been found to be non-linear (Bannerot and Austin 1983). Fishery biologists have long recognized variability in CPUE results from problems of gear efficiency due to interacting biotic and abiotic factors affecting fish movement.

Common occurrences with CPUE studies include spatial correlation among sampling units, inverse nonlinear relationships between capture efficiency and population abundance, and skewed frequency distributions for CPUE with zero catch being the most frequently recorded catch (see review in Thornton et al. 1986). The high variability among units of sampling effort (catch per net hour or per net night) may result in poor statistical resolution of stock means or patterns of population fluctuations (Bannerot and Austin 1983, Thornton et al. 1986).

Due to the relationships between CPUE and fish abundance, use of CPUE will provide only semi-quantitative estimates of fish abundance. Based upon CPUE, assessment of fish presence/absence must be considered qualitatively (Thornton et al. 1986).

Transformed catch data and the relative frequency of zero CPUE have been demonstrated to be the best indicators of population abundance. Catch data should be reported as catch per net hour or per net night (means and variances) for each species captured. The square root transformation of catch data should be used (Bannerot and Austin 1983).

3.9.5.2 Population Age Structure - Evaluation of population age structure is dependent upon obtaining a representative sample of the overall population. As noted above, passive fishing techniques using gill nets tend to produce skewed data with older and younger fish being less efficiently captured. Additionally, aging of fish by reading of scales is most accurate in the age

I-IV classes for alpine salmonid fisheries. Thus, presence/absence of Y-O-Y and older age classes generally will be qualitative. Age frequency distribution within the I-IV age classes will be most quantitative.

Captured fish should be aged by scale readings using standard techniques (Lagler 1956, Jerald 1983). As with CPUE, age frequency data generally should be transformed to achieve independence of variance and mean. The square root transformation has been found to be most useful (Bannerot and Austin 1983).

3.9.5.3 Condition Factors - Weight and length are quantitative attributes of individual fish that can be easily measured in the field. Relationships between weights and lengths give an indication of the relative abundance of food and relative quality of habitat for growth. Condition factors for each age class I-IV should be calculated according to:

$$C = (W \times 10^5) / L^3$$

where: C is condition factor
W is weight in pounds
L is total length in inches

(Note that condition factors are reported typically in English units. For comparison to existing data from state game and fish departments it probably is best to continue using English units - e.g., Remmick 1984.)

3.9.5.4 Growth and Mortality Rates - If sampling of existing fish stocks has been random among age classes, determination of growth and mortality characteristics from catch data reveals important characteristics of the fish stock for a particular lake. The dependent variables most commonly related to water and habitat quality include average annual growth increment, instantaneous growth rate, average length at a given age, and instantaneous total mortality. Again, age classes I-IV should be used to provide the most accurate calculations.

Average annual growth increment between growth intervals of 1-2 cm can be determined by back-calculation techniques using length at age i, determined by scale analysis (Lagler 1956, Whitney and Carlander 1956, Carlander 1981). Fish growth rates also should be calculated using length-weight regression assuming allometric growth: $W = aL^b$, where a and b are growth coefficients.

Instantaneous growth rate is calculated as the difference between natural logarithms of weight for consecutive age groups (Everhardt and Youngs 1981). Instantaneous total mortality (TM) is calculated from the slope of the regression of age classes verses frequency:

$$N_i = N_{i-1}e^{TM}$$

where N^i is number of individuals found in i^{th} age class.

In lakes where harvesting mortality by fishermen is small, TM represents an approximation of natural mortality of the population.

3.9.5.5 <u>Missing or Weak Year Classes</u> - Observations of missing or weak year classes in a fish stock may be indicative of changing habitat conditions or density- independent mortalities, resulting primarily from weather. For anthropogenic change related to atmospheric deposition, it must be recognized that missing or weak year classes are common occurrences in wild fish populations, and that gear inefficiency and poor age determinations preclude accurate estimates of older age class strength. Thus, for a given lake, the occurrence of missing or weak year classes in catch data is not a definitive characteristic of the fishery. However, patterns of similar age-frequency distributions (number and sequence of low frequency year classes) among monitored lakes in the same region may be indicative of regional conditions or change (Thornton et al. 1986).

3.9.6 <u>Detection Goals</u>

Presently, there are no standard references that quantitatively define detection goals for changes in the fishery indices discussed for high-elevation salmonid fisheries. Comparable analyses of fishery data from remote lakes using stock assessment by gill netting are being conducted by the U.S. Environmental Protection Agency as part of the National Surface Water Survey. Results of these analyses, which are expected in several years, will help define realistic detection goals for some salmonid species with restricted stock sizes and for limited sampling.

It must be stressed that due to inherent variability in gear efficiency between lakes, fishery statistics cannot be compared between different monitored lakes but only within a given lake over a sequence of years.

Based upon reasonable age determination of one- to four-year-old fish changes may be detected in relative growth and mortality indices on the order of 20-50% but achievement of these goals is uncertain. Estimates of changes in absolute characteristics of an alpine fish stock will be less precise. Changes in the neighborhood of only 2-3x will be considered valid on the basis of reasonable adherence to assumptions of random sampling of fish stock and independence of variances and means. Estimates of age will be particularly troublesome. In general, aging by scale reading produces estimates of higher mortality rates than actually are present due to poor aging of older fish on the order of 10-20% to high (Jerald 1983). Estimates of the precision of age determinations should be done according to Chang (1982).

3.10 Macroinvertebrates

Macroinvertebrates have been observed to be sensitive to low pH conditions in lakes and streams and can be used as a functional part of the warning system established to monitor possible effects of air pollution in high-elevation ecosystems. Aquatic macroinvertebrates are animals without backbones that live in streams and lakes and are big enough to be seen without a microscope when in advanced stages of their development. Tolerances of aquatic invertebrate species vary according to their specific anatomical, behavioral, and physiological adaptations. Since some are more tolerant to acid conditions than others, their communities offer a graduated barometer which indicates the severity of the problem and when correlated with chemical and physical data, can provide a vital tool for early detection of environmental degradation.

The following equipment and procedures are being used by federal and state agencies in western regions of the United States, and would provide a common basis for collection of macroinvertebrate data to monitor effects of air pollution in high mountain ecosystems.

3.10.1 Equipment

Equipment needed for macroinvertebrate sampling is listed below:

Modified Surber net (see Figure 3-1)
250 micron sieve
3 plastic bottles per station with strip of masking tape attached for identification data
Preserving solution--ethyl alcohol plus one cup 10% formalin per gallon of 70% alcohol
Hip boots
Saturated salt-water solution
Two aluminum bread pans
Waterproof gloves (scuba diving or rubber electrical types recommended
Laundry pen (waterproof marker)
Long-handled kick net
White plastic try--2.5" x 10" x 12"
Fine-pointed forceps

3.10.2 Sampling Station and Site Selection

Stations should be established in the inlet and outlet streams of the lake ecosystem to be monitored. The station should be established in a riffle area [having unimbedded rubble substrate (3-12" rocks), if possible]. Most of the macroinvertebrate species present will be found in the rubble substrate which has been called the "breadbasket" of the stream.

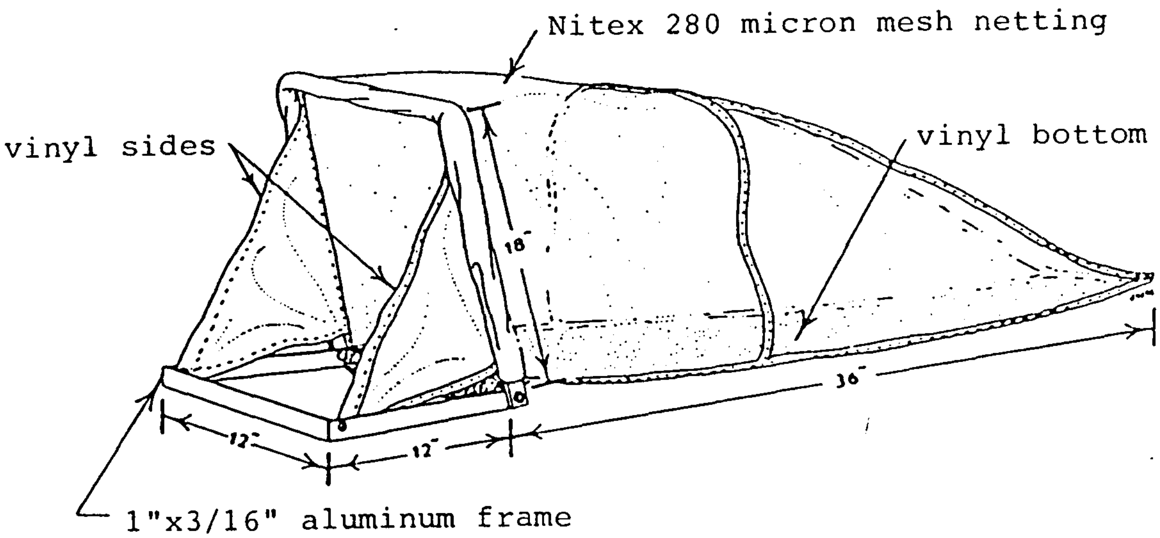

Figure 3-1. Modified Surber Sampler

3.10.3 Number of Samples

A minimum of three stratified random samples are taken at each station. This generally provides desired community representation and data which can be statistically analyzed. Four or more samples may be shown to be necessary on some streams depending on the statistical reliability desired. A station is defined as a designated stream reach up to 30.5 meters (100 feet) in length.

3.10.4 Sampling Frequency

Samples should be taken on a monthly basis during summer and fall. Limited access generally permits just three or four sampling dates annually.

3.10.5 Inventory Period

A minimum base period of three years is recommended to show effects of natural extremes in physical and water chemistry influences on an ecosystem, and a minimum frequency of three dates annually-- spring, summer, late fall.

3.10.6 Modified Surber Net Samples

The modified Surber square foot sample net has proven to have a correlation coefficient equal to or better than other currently used sampling devices. The 3-ft long net and 18-in high upper frame (Figure 3-1) eliminates the backwash problem often experienced with the original Surber net.

3.10.7 Sampling Procedure

3.10.1.1 Streams

1. The foot-square modified Surber frame is placed over the gravel-rubble substrate in the stream with the net downstream. As the rocks within the frame are scrubbed, the macroinvertebrates are carried into the net by the flowing water. The substrate underlying the gravel-rubble is also stirred to a depth of 3-4 in (7-10 cm), if possible.

2. After allowing the water to drain from the net, the net is inverted into an aluminum pan containing a saturated salt-water solution. As the salt water is poured into a second pan, the organic materials thus floated are caught in a 250 micron sieve. The salt water is then poured back into the first pan, the contents again vigorously stirred, and the floating materials and specimens are poured for a second time to the sample in the sieve. The sample may require sieving two, three, or more times.

3. The sample in the sieve is then washed from the sieve pan into the sample bottle with an alcohol solution (One cup 10% formalin per gallon 70% ethanol). Enough alcohol should

be added to the sample bottle to cover the sample. Caddisflies, in their cases, must be handpicked from the pan and added to the sample.

3.10.1.2 Lakes

1. Macroinvertebrate sampling within a lake should include qualitative lake-shore samples for sensitive indicator mayfly, stonefly, caddisfly and Amphipod species. these samples can generally be taken with a long-handled kick net used in a sweeping motion through vegetation or over the lake bottom substrate.

2. Portions of the net contents can be placed in a white tray with a small amount of water in the bottom for detection and removal of invertebrate fauna with forceps. If the net contains plant materials, put more water in the tray and vigorously wash the plants in the tray. The water and its contents are poured into the 250 micron sieve and then transferred to the sample bottle. The sample data on the bottle should include the words "Qualitative Lake Sample".

3. Numbers of individuals per species in the samples should reflect relative abundance of those species in the lake, which should also be recorded in field notes.

3.10.8 Data Evaluations

The USDA Intermountain Region Aquatic Ecosystem Analysis Lab has developed methods for macroinvertebrate sample and data processing (USDA Forest Service Intermountain Region Fisheries Habitat Surveys Handbook - R-4 FSH 2609.23, Winget and Mangum 1979). Analysis elements include a combination of physical, chemical, and biotic community factors and measurements.

Chemical parameter data used include the following:

1. pH - to identify high or low concentrations that may be detrimental or fatal to aquatic fauna.

2. Sulfate - concentrations over 50 mg/l are limiting to aquatic macroinvertebrates.

3. Alkalinity - which is closely linked to productivity and the buffering capacity of an aquatic ecosystem.

4. Other possible water quality components that could be significant to monitoring and analysis are metals, particularly aluminum for acid rain monitoring, and organic nutrients, NO_3 and PO_4.

Physical parameters used for streams include the following:

1. Percent gradient which indicates the maintenance capability of a stream.

2. Natural instream substrate composition as percent boulder, rubble, gravel, and sand-silt materials which reveals the number and types of niches available to the aquatic fauna.

The three main biotic analysis elements include the following:

1. The <u>Biotic Condition Index (BCI)</u> which measures a stream against its own potential and not that of other streams. The BCI is based upon mean community tolerance and is a composite of the tolerances of individual taxa or species found in the community which varies in response to intensity of perturbations in the ecosystem.

   In the calculation of BCI, the predicted community tolerance quotient (CTQ_p) is divided by the actual community tolerance quotient (CTQ_a) times 100. The BCI is calculated as follows:

   a) Determine
      Gradient percent
      Relative substrate dominance of
         Boulder (over 12")
         Rubble (3-12")
         Gravel (1/8-2.99")
         Sand/silt (under 1/8")
         (These are given a ranking number of between 1 and 4 according to dominance)
      Total alkalinity (mg/l)
      Sulfate (mg/l)

   b) Using the above information and the key in Exhibit 5 in Chapter 5 of the USDA Forest Service Intermountain Region Fisheries Habitat Surveys Handbook (R-4 FSH 2609.23), determine the predicted community tolerance quotient (CTQ_p) for the reach on the study stream.

   c) Take 3 or 4 quantitative macroinvertebrate samples at a station and have them processed at the Regional laboratory to obtain a list of taxa with tolerance quotients (TQ) for each taxon. Statistical analysis of macroinvertebrate communities found living in a wide range of natural conditions revealed individual tolerances to natural phenomena. According to their tolerances to natural conditions, macroinvertebrate taxa were assigned numbers from 2 to 108. Higher numbers indicate higher tolerances to natural phenomena.

Exhibit 6 (R-4 FSH 2609.23) shows a cluster dendogram based upon the Jaccard Similarity Index which depicts the frequency of co-occurrence of 54 taxa. The strong clustering of taxa with similar tolerance quotients is highly significant. This illustrates the credibility of the determinants (physical and chemical) selected, the weighted values given each, and the TQ's assigned these 54 taxa. This was helpful in developing a list of taxa and their TQ's (Exhibit 7, R-4 FSH 2609.23).

d) Sum the TQ values and divide by the number of taxa to get the actual community tolerance quotient (CTQ_a),

$$TQs/n = CTQ_a$$

e) Determine the Biotic Condition Index,

$$BCI = (CTQ_p/CTQ_a) \times 100$$

The scale of BCI values listed below can be used as an indication of the health of a stream ecosystem upon which a defined management strategy can be based for each stream reach.

Scale	BCI
Excellent	Above 90
Good	75-90
Fair	Below 75
Poor	Below 75

The BCI

i) is sensitive to all types of environmental stresses,
ii) is applicable to various types of streams,
iii) gives a linear assessment from unstressed to highly stressed conditions,
iv) is independent of sample size providing the sample contains a representative assemblage of species,
v) is based on data readily available or easily acquired;
vi) meshes readily with, and supports, existing stream habitat and/or water quality management programs.

2. The DAT Diversity Index combines a measure of dominance of species in the community and the number of species present. Many other indices measure on or the other of these aspects.

The procedure for determining DAT is as follows: The dominance part of the index is determined by placing a sample of aquatic insects in a petri dish with lines marked on the bottom. As on views the insects through a dissection microscope, each species is identified as the dish is moved snake fashion, not viewing the same organism twice. Each organism viewed is counted and each series is also counted. A series is recorded each time a species sighted is different from the last one seen. If the sample has a

sufficient number of organisms, 300-400 should be observed to determine the diversity index value.

The number of series (s) is divided by the number of organisms (o) to determine the dominance value (Dom. = s/o) which will be a fraction between 0 and 1. The number of taxa in the sample is multiplied by this dominance value to obtain the DAT Diversity Index (Dom. x Taxa = DAT).

DAT Scale	Stream Value
18-26	Excellent
11-17	Good
6-10	Fair
0-5	Poor

3. Macroinvertebrate Standing Crop is determined by the dry weight of the organisms for each sample. Small aluminum pans are predried for 8 to 16 hrs and are weighed to the nearest tenth of a milligram on Mettler balance. The samples placed in these pans are dried at a temperature of 175° F for 8 to 16 hrs; then, the pan and its contents are weighed. This is important to indicate whether a stream is reaching its potential and shows its potential for supporting a resident fishery. Exhibit 8 (R-4 FSH 2609.23) shows some of the more common aquatic insects used in aquatic ecosystem analysis.

3.10.9 Other Analysis Elements

The following data are helpful in evaluations of aquatic ecosystems and sampling:

1. Total Number of Species is an indication of macroinvertebrate community diversity. This often gives an initial indication of the stability of the environment or of the community within the environment.

2. Mean Number of Organisms per Taxa per Square Meter is an indication of the stability of the community, habitat, and water quality. Taxa may be present as transient individuals or as resident populations which may indicate whether conditions are favorable or not.

3. Standard Error of the Mean is a measure of similarity in samples which indicates when enough samples have been taken to obtain the desired reliability.

   According to EPA standards, this value should be under 20% and on most streams, this can be achieved with 3 samples; some streams require 4 or 5 samples. The formula is shown as

$$\text{Percent Standard Error of Mean} = \frac{\frac{S}{\sqrt{n}}}{x}$$

The Standard Deviation (S) is divided by the square root of the number (n) of samples and the quotient is divided by the mean (x) number of organisms in the replicate samples.

4. Coefficient of Variation is a value that indicates variability in samples. It is independent of the number of samples. It evaluates the sampling technique and/or effectiveness of the sample equipment. EPA has set the standard at under 50% for acceptable reliability. The formula is

   Coefficient of Variation = S x 100/x

   The Standard Deviation (S) is multiplied by 100 and the product is divided by the mean (x) number of organisms in the replicate samples.

5. Standard Deviation is a measure of sample variation and indicates whether sampling technique and number of samples are sufficient to effectively show community structure.

   Tolerance values (quotients) are based upon the tolerances of macroinvertebrates to natural environmental factors. Tolerances have been observed for many taxa to specific environmental perturbations including those caused by man.

   Knowing the tolerances of various taxa in an aquatic ecosystem generally provides a graded scale of tolerances to acid-waters. Knowing how those genera have reacted to aquatic ecosystems where acidic conditions have developed and intensified over time or when comparing communities upstream and downstream from a source of acidification gives a good indication of specific tolerance levels for those taxa. This information would be sufficient to detect ecosystem stress conditions more easily and quickly than by use of any other monitoring tool, particularly if baseline data has been established in the drainage.

   The next step would be costly and time consuming initially but would sharpen this tool for detection of change. If the local species could be tested for tolerance to increased acidic waters in a flowthrough, simulated system under as close to endemic conditions as possible; their presence in previously unmonitored ecosystems or absence from monitored ecosystems where they had been recorded could provide an excellent system for evaluating conditions.

3.11 References

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WORK GROUP 4
FLORA

4.1 Purpose

These protocols are designed to assist the Federal Land Manager (FLM) in designing a measurement program capable of determining the current, and monitoring future, responses of the flora (AQRV's) to atmospheric pollution. These protocols are general guidelines rather than specific methods. They are flexible and guide the FLM in the development of a program which would be suitable for a specific permit and wilderness area.

These protocols are built on the ongoing programs of several regulatory agencies which assess the effects of pollution on native plants (see Bennett 1984, 1985), but they represent a new synthesis and approach to the problem. The protocols are based on the acceptance of the principle that changes should be detected in "the most sensitive part of the ecosystem." They are presented as the most efficient and parsimonious steps to make decisions involving present or future effects of atmospheric pollutants.

A primary goal is to obtain measurements of floristic AQRV's within a short period, e.g., one growing season, which can be used in the permitting process. However, if funding and the management policy of the Class I area under consideration allow, a secondary goal would be to establish subsequent trends and changes via long-term measurements.

4.2 Constraints and Philosophy of Approach

Biological AQRV's worthy of measurement are inherently more difficult to identify than abiotic AQRV's. Further, the interpretation of the significance of their measured value as an indicator of air quality is often ambiguous. The following points provide the background for this comment:

- o No finite list exists of organisms and communities equivalent to that of criteria pollutants.

- o Because of the lack of adequate controls and experimental design, any field observation or sampling will lead only to correlations and inference and not to an established cause and effect of a pollutant on a biological AQRV unless chronic levels of pollution are encountered.

- o No known functional attributes exist which respond only to specific changes in air quality. The majority, if not all, functional attributes also will be affected by several pollutants and by natural environmental factors. Synergism will occur between the various controlling factors. Further, some symptoms may have more than one cause, including those other than pollution.

- o Species and individuals vary in their response to environmental stress because of genetic or ecotypic variability. Other interactions can complicate the picture. For example, stresses can be mitigated or amplified by temporal patterns of the plants or by involvement with pathogenic organisms.

- o Even the functional attributes which may be reasonably related to changes in air quality are poorly quantified. Even if the dose-response experiments have been done, extension to the field is tenuous. An overall ignorance of the norm makes many attributes, especially physiological ones, of little value.

Measurements in these western high elevation and montane Class I areas present further difficulties:

- o These areas tend to be large, inaccessible, diverse, and spatially heterogeneous.

- o The air quality history or current status of air quality may be poorly known.

- o The effects of air quality on the native plants, communities, or biotic systems are not fully known.

There are two key elements to the protocols. The first is the decision to deal with the floristic component of the plant system rather than higher attributes of the ecosystem. The second key element is the flexibility and general nature of these protocols which do not provide exact sampling and measurement schemes. Flora rather than vegetation is the operational perspective which focuses on the presence and performance (health) of individual plant species and their populations, rather than on attributes of vegetation, communities, or ecosystems. The scope of measurement is further reduced by the restriction only to known sensitive taxa and their sensitive systems. The complexity of higher order ecological units such as community and ecosystem and the difficulty of measuring change in these units provide ample reason for a floristic perspective to take precedence over a vegetational or total system perspective. Nonvascular plants such as mosses and lichens are included as part of the flora to be considered because of their known sensitivity to air pollution and their established usefulness as indicators; algae, bacteria, and fungi are not included. The flexibility of the protocols is justified on the basis that unique programs have to be designed by the FLM and contributing experts to meet the unique characteristics of each permit, each area, and each flora.

There are two parts to the protocols: 1) a flow diagram or decision tree with text explaining the step-by-step process for designing a specific program, and 2) some general guidelines for sampling and analysis procedures. The decision regarding permit

denial or approval is beyond the scope of these protocols, but for perspective and relevance the position of the process is shown in the flow diagram.

4.2 Protocol Design

The flow diagram in Figure 4-1 shows the data sets which are required at the start of the design process and the decisions necessary to design a measurement program. The required data are shown in lettered boxes and the processes and decisions, here called steps, in numbered boxes.

In order to decide what, when, and where to make measurements of the flora, a number of data sets are required. These may be available in the literature or specific archives pertaining to the Class I land under consideration. If not available, they should be compiled by the FLM. Available information seldom will be adequate and preparation of this information will be a mandate and prescription of the area. These compilations may require assistance from experts. In the sequence of the lettered boxes of Figure 4-1, the data sets required for each Class I area are described.

(A). Floristic List. A complete list of vascular plants, lichens, and mosses is needed. This list should show for each species a commonness rating (e.g., abundant, frequent, rare) and distributional information (e.g., habitat and soil preferences and vegetation associations). Reasonable lists of vascular plants are available for many Class I areas. If this is not available, local floras, herbarium collections, and consultation with local systematic botanists can supply a reasonably complete list which will include estimates of commonness. Available lists of lichens and mosses rarely will be available and their compilation will not be easy without field surveys by specialists. Distributional information will seldom be pre-compiled but can usually be derived from such sources as floras, plant ecology dissertations, and plant community descriptions from similar nearby regions.

(B). Land Cover Map. A map of land cover units at the largest reasonable scale (1:24,000) would be satisfactory. The land cover units should be based primarily on vegetation assemblages. Each vegetation unit should be described by species content and abundance and may be additionally defined on the basis of other attributes such as geology, soil, and habitat. Maps of species distribution, if available, would be particularly useful, especially for rare species whose distribution is difficult to interpret from a vegetation map. Adequate land cover and/or vegetation maps will only be available for a few areas. Forest inventory maps, soil surveys, and geology maps may be more readily available and may provide background data for land cover maps. Most Class I areas will have reasonable air photo coverage and a skilled air photo interpreter with the help of a local plant ecologist can produce adequate land cover maps overlaid on USGS topographic maps. The comprehensive method of

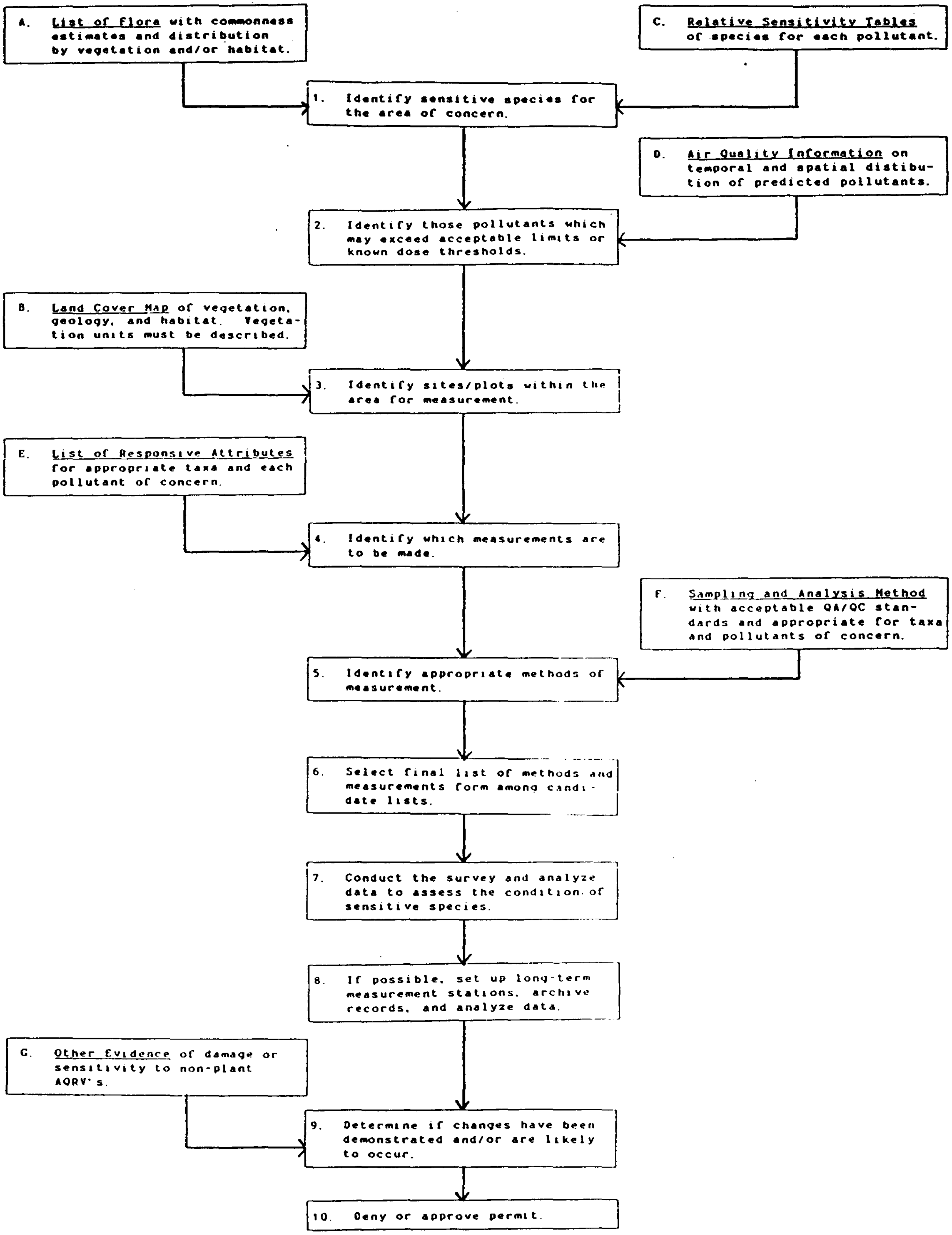

Figure 4-1. Flow diagram for the use in designing a measurement program to assess effects of pollutants on plant AQRV's.

Kuchler (1967) is recommended. The description of vegetation in terms of its composition is critical to the proposed protocol. According to the Kuchler method, this information is gathered as the map is ground-truthed and revised.

(C). Relative Sensitivity Tables. A fundamental assumption of monitoring air pollution effects on plants is that not all species are sensitive to a given pollutant. Therefore, candidate test species must be sensitive to a given pollutant. Furthermore, we agree with Cairns (1986) that there will also be no single reliable most sensitive indicator species for specific pollutants. Therefore, several test species must be selected. Lists of relative sensitivity of plants to specific pollutants may be found within the literature (e.g., Applied Science Associates 1976, Davis and Wilhour 1976, and Table 4-1). The EPA Criteria Documents for each pollutant are also a useful source of lists. National experts also are useful contributors of information at this point. When information is not available for the actual species of the study area, attention might be given to related taxa or growth-forms which often, but not always, have similar sensitivities to a pollutant.

(D). Air Quality Information. This is required to identify the probable pollutants of concern. Sources of these data will be any previous monitoring, the direct monitoring provided as part of the total protocol (Working Group I of this report), and from the permit-application itself. The most desirable data set would contain temporal and spatial distribution of pollutants and also the frequency concentrations of each pollutant over the area. Atmospheric modeling is often the best source of this distributional information.

(E). List of Responsible Attributes. It is necessary to measure only those attributes of sensitive species which show clearly diagnostic responses to pollutants. Injury atlases illustrating damage and stress symptoms are a good source of clues as to appropriate attributes to measure; for example, Jacobson and Hill (1970), U.S. Forest Service (1973), Malhotra and Blauel (1980), and Thompson, et al. (1984). Table 4-2 illustrates the type of required information. This information is required for each pollutant of concern.

(F). Sampling and Analysis Procedures. For each species and attribute, there will be an appropriate method of assessment of pollutant effect. The fifth column of Table 4-2 lists such methods. Handbooks with acceptable methods must be found or developed and refined as necessary. Section 4.4 further discusses these methods and sources.

(G). Changes in Non-Floristic AQRV's. This information is included in the decision tree to illustrate a complete permitting process. Procedures are outlined in other sections of these protocols to measure non-floristic AQRV's.

Table 4-1 Partial example of Species Sensitivity Chart required as input in the decision process (from Applied Science Associates 1976).

PLANT	O_3	PAN	SO_2	F	NO_2	2,4-D	Cl	NH_3	HCl	Hg	H_2S	Ethylene
Acacia *Acacia sp.*												T
Adonis *Adonis sp.*									T			
Ageratum *Ageratum sp.*												I
Alder *Alnus sp.*	I		S									
European Black *A. glutinosa (L) Gaertn.*									I			
Alfalfa *Medicago sativa L.*	S	I	S	T	S		S					
Aloe *Aloe sp.*										T		
Anthurium *Anthurium sp.*		T										
Apple *Malus sylvestris Mill.*		T	S	I	S	S						
Apricot *Prunus armeniaca L.*	T											
Chinese *P. armeniaca L. var. Chinese*	I			S								
Moorpark *P. armeniaca L. var. Moorpark*				I								
Royal *P. armeniaca L. var. Royal*				S								
Tilton *P. armeniaca L. var. Tilton*				I								

S = Sensitive; I = Intermediate; T = Tolerant

Table 4-2.

Examples of the Kind of Measurement and Methods Required for the Detection of Changes in Two Atmospheric Pollutants

Pollutant	Sensitive Taxa	Responsive Attribute	Measurement	Sampling Method
Sulfur dioxide (LeBlanc and Rao 1975, Hale 1982, Wetmore 1983)	Lichens (e.g., <u>Xanthroparmelia cumberlandia</u>)	Disappearance of taxa	Former and present range	From published lists and maps, from herbarium searches, and below
		Frequency of occurrence	Present range and frequency	Broad areawide surveys, distribution mapping
		Sulfur content of greater than 2%	Tissue analysis	Epiphytic thalli to be collected from relocatable plots
Ozone (Heath 1975, Stolte and Bennett 1986)	<u>Pinus</u> <u>contorta</u> (lodgepole pine)	Foliage	% leaf flecking Representative leaf length % leaf retention	Plots located within the specie range using vegetation map--should be accessible to trails or roads, have more than 30 trees healthy and large enough to allow repeated sampling. 5 branches are sampled from each tree.

4.3 The Decision Process

With the assembled data and information sets on hand, the selection of the measurement methods can be made. The flow diagram illustrates this process with numbered steps. At step 1, the potential study species are identified by comparing the floral list (A) with the list of sensitive species given in the sensitivity tables (B). At step 2, the potential pollutants, i.e., those which may increase to unacceptable levels, can be derived from the air quality information (D), and at step 3, a match of this information with a list of species with known sensitivity to the appropriate pollutant (C) helps to set priorities for studies in the area of concern and leads to the identification of sites at which measurement could be made. Sites where the sensitive species are present may be determined from the land cover and species distribution maps (B). Site selection should also be made with consideration of predicted or known pollution patterns (D). If pollutant distribution data is not available, then the sensitive species must be monitored over its entire range. If the areas over which elevated pollutant levels are expected to occur overlap with the distribution of sensitive species then these areas should be intensively monitored. Those areas which are less likely to be impacted should also be monitored. Final placement of study plots or location of samples will depend on which plant attributes are to be monitored. Step 4 decides which measurement are to be made. Table 4-2 provides and example of data for set E and lists for two pollutants and some sensitive taxa those attributes which are responsive or readily affected by the pollutant. For example, in Table 4-2, we see that needle length and needle retention in _Pinus contorta_ are affected by ozone levels. Similarly, step 5 decides the methods of appropriate measurement. For example, for _Pinus_ foliage, the of Stolte and Bennett (1986) using large-scale random sampling would be a good candidate.

Step 6 would be to select a final list of methods and measurements from among a candidate list derived in steps 4 and 5. Final selection will depend on many considerations; for example, the presence of sensitive species and attributes, the availability of effective methods, available labor and time, and coordination with other ongoing monitoring programs. Often the permit decision must be made in a very short time frame of less than a growing season. In such a case, the FLM would proceed to step 7. An important decision included in the next step is whether only short-term studies are mandated or whether long-term monitoring can be attempted. (Stategies for long-term monitoring sites are discussed in Section 4.5.) From a scientific and a protection point of view, long-term studies (step 8) are desirable. They will provide the most reliable assessment of effects and also easier decisions in the case of future new permit applications and permit reviews. Therefore, it is recommended that, within constraints of funds and time, step 8 be given serious consideration. This can be done concurrently with short-term assessments, or to build on short-term data sets gathered during expediently made permit assessments. Following

the surveys and analyses (steps 7 and/or 8) the FLM must review the information and determine as per step 9 the health and risk of the floristic components of the Class I area. Other evidence (G) will be brought to bear on this by the FLM during the PSD permitting decision proper.

4.4 General Guidelines for Sampling and Analysis

Sampling and analysis will depend on the species and attributes selected in the search for sensitive systems and also upon whether long-term monitoring or only short-term survey studies are being entertained. This section addresses the short-term studies while long-term monitoring strategies are discussed in Section 4.5. Within reason, we recommend that both monitoring and survey methods be as similar as possible--similar with regard to sample size and permanent marking or accurate location of sampling points or plots. Sample size should always be adequate. Methods manuals should provide this information, but if new methods are developed, a competent statistician should be consulted.

Sampling along gradients of airflow, and thus along possible gradients of pollution, provides better evidence for cause and effect. If long-term sampling is initiated, the pollutant can be regarded as an independent variable and the effects of other factors such as naturally fluctuating climatic factors can be taken into account. Further information on cause and effect develops as the database grows over time and when reliable co-measurements of physical and chemical factors are collected. The re-sampling of permanent plots and tagged individual plants over time reduces the problem of spatial variability. Most growth and physiological activities decline in late summer and early fall; sampling at this time can reduce seasonal and temporal variability.

In most cases, potential gradients of air flow or pollution will not be known or pronounced enough to know how to locate sample points. Therefore, we generally favor the random placement of plots or transects within the system which contains the species of concern. Permanent marking is to be preferred and, if necessary, stubbornly lobbied for in those Class I areas where managers may object. There are markerless methods but they are costly and not always reliable. Methods of marking with minimum impact are discussed in Zedaker and Nicholas (1986). We recommend that each study plot be thoroughly described by the methods of Walker et al. (1979). These descriptions form a necessary database and give clues as to factors controlling plant stress other than pollutants. Photography of plots and individual plants is a valuable supplement to plot description. Photographs can record for posterity what the observer hasn't yet learned to spot or what doesn't seem important at the time.

Table 4-2 illustrates the types and methods of measurement which could be used for the two pollutants, ozone, and sulfur

dioxide. The table further illustrates the kinds of considerations that FLM's and experts will need to make in deciding an appropriate measurement and its sampling method. Some annotations concerning ozone and sulfur dioxide effects will help illustrate the process of method selection.

Ozone does not leave a residue within the plant to be measured whereas sulfur dioxide may be retained as sulfate or some other sulfur compound. Therefore, tissue chemistry is not useful for ozone detection; assays of products of oxidation from ozone injury are not appropriate in field techniques since the products are ephemeral. Lichens and bryophytes are not sensitive to ozone and would, therefore, not be used in an assessment of ozone effects. Some pines, however, are sensitive to both sulfur dioxide and ozone and assessment methods could be combined (see Stolte and Bennett 1985). We recommend the Milkweed measurement method of Bennett and Stolte (1985) as a model of an assessment method.

Analysis of tree rings for accumulated trace metals (Berisch and Ragsdale 1985) and for reduced growth resulting from poor air quality (Nash et al. 1975) are attractive methods since they have the potential to show previous regimes of effects of pollutants on growth. Generally, however, we caution against tree ring analysis since it is technically demanding and expensive. Also, any reduced growth effects can seldom be related to specific pollutants.

Perhaps the most difficult part of the floristic protocols will be the determination of the significance of observed plant responses and what the continued or ultimate consequences or those responses imply for the plant population. It is upon these prognoses that the permitting decision will rest.

4.5 Long-Term Monitoring - Measures and Basic Sampling Design

When a specific pollutant is not identified, or for such concerns as acid deposition that cause ecosystem-level effects, it is recommended that a basic and long-term monitoring effort be conducted.

Table 4-3 lists the principal attributes recommended for measurement. Tables 4-4 through 4-7 provide some sample forms and scales for field measurements. The basic sampling design calls for several equivalent landscape units, such as small alpine basins, to be surveyed and mapped. These units should be selected, wherever possible, along known or predicted airflow paths where gradients of pollution might be expected. Permanent plots that contain the growth forms being studied should be established within each basin. These growth forms are fruticose and foliose lichens, evergreen plants, and trees. Individual plants or plant parts should be permanently tagged.

Table 4-3.

Measurements for Vegetation and Plant Baselines and Monitoring

Attribute	Method	Reference
<u>Vegetation Map Units</u>		
Species composition	Releve	Walker et al. 1979
Site factors	Releve	Walker et al. 1979
Soils and geology	See Work Group 2	
<u>Permanent Plots</u> (50X50m)		
Photographs		Walker et al. 1979
Site factors		Walker et al. 1979
Soil	See Work Group 2	
Species Composition		Walker et al. 1979
- Cover value for shrubs, herbs, and ground layer		
- Density and diameters for trees		
<u>Fruticose and Foliose Lichen Plots</u> (20X25 cm)		
Photographs	35 mm camera	Hale 1982
Species check list	Listing	Hale 1982
Plant Chemistry		
- Pb, Cd, Zn, Ni, Cu, Mn	Atomic absorption ashing and HNO_3	Allen et al. 1986
- Sulfur	Leco combustion to SO_2	See Work Group 2
<u>Evergreen Plants</u>		
Leaf necroses and chloroses	Comparison with color standards	e.g., Jacobson and Hill 1970
Elemental analysis	Atomic absorption ashing and HNO_3	Allen et al. 1986
Leaf retention by age class	See text	

Table 4-3. Continued

Attribute	Method	Reference
Trees		
Tree ring growth analysis for each site	Tree coring and dendroecology	Nash et al. 1975
Historical record of pollutant deposition Pb, Cd, Zn, Ni, Cu, Mn,	Ashing and HNO_3, atomic absorption	Berisch et al. 1985

Table 4-4.

Sample Form for Releve Site Factors

Releve No. ________ Map Name ____

Observer __________________________ Date _______________

Master Map Code ___________________ Map Unit No. _______________

Site Description and Site Factor Code (see Table 4-5) __________

____

____

Sample Area _______________________ Depth of Thaw ______________

Slope Aspect ______inclination° _____ Depth of Water ___________

<u>Site Scale</u> (1-10):

site moisture ________________

soil moisture ________________

temperature ________________

snow ________________

wind ________________

surface age ________________

stability ________________

cryoturbation ________________

fire ________________

<u>Relief</u>:

<u>Microrelief</u>:

Type ________________

Height ________ Width ______

<u>Mesorelief</u>:

Type ________________

Height ________ Width ______

(fire evidence ______________)

<u>Vegetation</u>:

Age of Vegetation: Estimate _______________ Evidence __________

<u>Percentage Cover</u>:

All vegetation________________

Trees(>2m) ________________

Tall shrubs(>2m) ____________

Medium shrubs(.5-2m) _________

Dwarf shrubs(10-15cm) ________

Prostrate shrubs(<10cm) ______

Graminoids ________________

Forbs ________________

Bryophytes ________________

Lichens ________________

Rocks ________________

Bare soil ________________

Water ________________

<u>Height</u>:

Tree layer(m) ____________

Shrub layer(m) ____________

Herb layer(cm) ____________

Ground layer(cm) __________

<u>Biomass</u> (scale 1-10):

Overall ________________

Tree layer ________________

Shrub layer ________________

Herb layer ________________

Ground layer ________________

<u>Photo Nos.</u> ________________

Table 4-4. Continued

Releve No. ____________________

Animals:

Name	Scale (0-3)	Evidence
Bear	________	____________________
Caribou	________	____________________
Moose	________	____________________
Lemmings	________	____________________
Microtines	________	____________________
Ground squirrels	________	____________________
Ptarmigan	________	____________________
Other birds	________	____________________
Insects	________	____________________
Others	________	____________________

Plant Phenology:

Species	Stage
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

Soil:

Soil type ____________ Parent material ____________

Description (include horizon names, depths, color, texture, structure, character of boundaries, %rocks, %fibre, %mottles):

Photo Nos. ____________ Soil sample top 10 cm ________

Disturbance:

Type ________________ Age ________________

Notes ____

Checklist:

( ) Mark location on photo ( ) Soil photo
( ) Mark location on map ( ) Vascular plant sample
( ) Soil sample ( ) Moss sample
( ) Tree core ( ) Lichen sample
( ) Vegetation photo ( ) Permanent plot staked & marked

Table 4-5.

Subjective Environmental Gradient Scales

Site Scales:

Scale	Site Moisture	Soil Moisture	Summer Air Temperature	Snow	Wind
1	Very dry, little or no moisture within 10 cm of surface, exposed to strong winds	Very dry, no apparent moisture, no clumping	Very cold sites, high altitude with north-facing slopes	Little or no snow cover in winter, ridge rop sites	Completely sheltered from the win
2	Very dry, little moisture near surface, somewhat less exposed sites	Very dry, some moisture but doesn't clump	Cold sites, high altitude with moderate solar exposure, north-facing coastal plain sites or flat sites extreme arctic coast	Little or no snow cover in winter, exposed slopes	Exposed to occasional very light (1-5km/hr) winds
3	Dry, some moisture near the surface, very exposed	Dry, clumps but then crumbles	Cold sites, moderate altitude flat coastal plain sites	Slopes usually snow covered in winter	Very light winds common
4	Dry, some moisture near the surface, somewhat less exposed sites	Dry, clumps and stays in a ball	Cool sites, flat surface in Arctic Foothills	Slopes snow covered in winter, snow melt by late May	Occasional light (5-10 km/hr) winds
5	Moist, top 10 cm continually moist to wet, moderately well-drained sites	Moist, binds but can be taken apart	Moderate temperatures, south-facing slopes on Arctic Coastal Plain or high mountains	Shallow depressions, somewhat prolonged snow cover, melt by early June	Light winds common
6	Moist, top 10 cm near saturation, less well-drained sites	Moist, binds completely into gooey ball	Moderate temperatures, south-facing slope, Arctic Foothills	Snow patches, snow melt by late June or early July	Occasional moderate (20 30km/hr) winds
7	Wet, continually saturated soil but no standing water	Wet, can squeeze some water out	Moderate temperatures, flat site at intermediate altitudes south of Brooks Range	Snow patches somewhat later snow melt by late July	Moderate winds common

Table 4-5. Continued

Site Scales:

Scale	Site Moisture	Soil Moisture	Summer Air Temperature	Snow	Wind
8	Wet, usually with standing water early in summer	Wet, can squeeze lots of water out	Warm temperatures, flat site, lower altitudes south of Brooks Range	Snow patches, later snow melt, early August	Occasional strong winds (40-50km/hr) winds otherwise light
9	Very wet, usually with standing water late in summer	Very wet, totally saturated	Warm, south-facing slopes at intermediate altitudes in interior Alaska	Snow patches, very late snow melt, late August	Strong winds common, wind otherwise moderate
10	Very wet, deep standing water year round	Very wet, soil taken from under-water	Warmest south-facing slopes at lower altitudes in interior Alaska	Snow patches, very late snow melt, sometimes may have snow cover all year	Strong winds common, occasional very strong (>60km/hr) winds

Table 4-5. Continued

Site Scales:

Scale	Surface Age	Stability	Cryoturbation	Fire
1	Constant disturbance	Completely unstable always moving (e.g., dunes)	0% of surface disturbed	No evidence
2	Less than 1 yr since severe disturbance	Annually unstable (e.g., avalanche slopes, river bars)	< 1%	Buried charcoal
3	1 - 10 yrs	Periodically unstable (e.g., 50-yr flood plain)	1-2%	Charcoal on surface rare
4	10 to 100 yrs	Unstable, vegetation in patches, on slope	2-5%	Charcoal on surface common
5	100 to 1000 yrs, last disturbance during late Holocene	Unstable, vegetation in patches, on flat	5-10%	Older burn, living trees have burn scars
6	1000 to 10,000 yrs, last disturbance during early to mid-Holocene	Moderately stable, open vegetation, on slope	10-15%	Older burn, regrowth of large trees (>15cm dbh)
7	Old surface, last disturbance during late Wisconsin (30,000 yrs B.P.)	Moderately stable, open vegetation, on flat	15-25%	Older burn, regrowth of moderate-sized trees (5-15cm dbh)
8	Old surface, last disturbance during early Wisconsin (30,000 - 70,000 yrs B.P.)	Stable surface, completely vegetated, moderate slope	25-50%	Recent burn, small trees and/or complete vegetation cover
9	Very old surface, last disturbance during pre-Wisconsin time	Stable surface, completely vegetated, slight slope	50-75%	Recent burn, no regrowth of trees
10	Very old unglaciated surface	Stablest surfaces, completely vegetated, flat	75-100%	Complete burn, no regrowth

Table 4-5. Continued

Vegetation Biomass Scales:

Scale	Overall	Tree Layer	Shrub Layer	Herb Layer	Ground Layer
1	Barren, very sparse vegetation	Scattered small trees (<5cm dbh)	Shrubs rare	Very widely scattered herbs	Very sparse
2	Prostrate scrub or lichen meadow	Scattered medium trees (5-15cm dbh)	Scattered dwarf shrubs (0.1-0.5m)	Scattered short herbs (<0.1m)	Scattered
3	Graminoid meadow	Open small trees	Scattered medium shrubs (0.5-2m)	Open short herbs	Open thin cover (<2cm)
4	Tussock graminoid meadow with thick moss	Closed small trees	Open dwarf shrubs	Closed short herbs	Closed thin cover
5	Dwarf scrub	Scattered large trees (>15cm dbh)	Closed dwarf shrubs	Open medium herbs (0.1-5m)	Open moderat thickness (2 5cm)
6	Scrub	Open medium trees	Scattered tall shrubs (>2m)	Closed medium herbs	Closed moder ate thicknes
7	Dense tall scrub or open small evergreen trees	Closed medium trees	Open medium shrubs	Open tall herbs (0.5-1m)	Open thick (5-15cm)
8	Open medium-sized trees or dense small tree (<5cm dbh)	Open large trees (>15cm dbh)	Closed medium shrubs	Closed tall herbs (0.5-1m)	Closed thick
9	Open large trees (>15cm dbh) or dense medium-sized trees (5-15cm dbh)	Closed large trees	Open tall shrubs	Open very tall herbs (>1m)	Open very thick (>15cm
10	Dense large trees (>15cm dbh)	Closed very large trees (>225cm dbh)	Closed tall shrubs	Closed very tall herbs	Closed very thick

Animal scales: 0 No sign
1 Slight evidence
2 Moderate evidence
3 Abundant evidence

Table 4-6.

Plant Taxa Form

Plot Number ____________________

SPECIES	LIFEFORM CODE	CODE NUMBER	PERCENTAGE COVER

Table 4-7.

Collection Label for Plant Specimens

Collection No. ______________________ Herbarium No. ______________

Plant Name ____

Field Name ____

Locality _____________________________ Plot No. _________________

Longitude ____________ Latitude ____________ Altitude ___________

Ecol. Notes: Moisture __________________ Slope _________________

Community ____

____

Collectors ____

Date ______________________

Table 4-6.

General Landforms

20	Dunes
21	active
22	inactive
25	Basin/depression
26	thermokarst basin
30	Plains
31	depositional
32	erosional
35	Flood plain
36	channel
37	active
38	abandoned
39	river bar/island
40	River terrace
41	depositional
42	erosional
45	small delta
50	Alluvial fan
51	active
52	inactive
55	Valley
56	depositional
57	erosional
60	Mesa
61	footslope
62	sideslope
63	crest
70	Hills
71	footslope
72	sideslope
73	crest
80	Mountain
81	footslope
82	sideslope
83	crest
98	Water

4.5.1 Requirements

Estimates of man-day and field equipment requirements are given in Tables 4-8 and 4-9.

4.5.2 Field Methods

The initial regional survey of plot establishment should be done during the first growing season. Plots should be located away from main trails and access points. Plot and plant tagging is done as inconspicuously and unobtrusively as is possible. Botanical sampling can be conveniently done in late summer and early fall after plots and plants have been selected and appropriately worked, recorded, and positioned. In subsequent years, field work can be restricted to resampling the attributes with a frequency of about three to ten years.

4.5.2.1 Survey and Plot Establishment

Landscape Unit Mapping. Aerial survey, local interviews, and small scale topographic maps will be used to select candidate landscape units. This selection should be made in cooperation with Work Groups 2 (Soils and Geology) and 3 (Aquatic). Small well-defined valleys containing forests and meadows with surrounding uplands would provide the required sample plots. Reconnaissance visits are required to make final unit selections. Several (at least five) landscape units should be selected along known airflow paths. An additional (up to five units) could be located in a cluster at the center of the airflow path. These additional units would serve to establish spatial and other natural variation of attributes.

Geobotanical mapping of each landscape unit using the Kuchler (1967) comprehensive method is preferred. Preliminary landform and vegetation boundaries and classification are made on acetate overlays of suitable aerial photographs. Color infrared photography at 1:60,000 works well. Following field checking and appropriate updating, boundaries can be easily transferred to a 1:24,000 USGS topographic base map.

Each final map unit should be characterized for vegetation and landform cover. The method of Walker et al. (1979), which uses the releve technique (Westhoff and Maarel 1978), is quick and appropriate.

Voucher collections of plants should be made when rare or plants of uncertain identity are encountered. Standard herbarium techniques should be used. Table 4.5 gives the needed plant collection information.

Soil information can be readily added to these geobotanical maps.

Table 4-8.

Manpower Estimates

Personnel	Number of Days/Year	
	Year 1	Years 3-10
Plant Ecologist	50	5
Plant Taxonomist	15	5
Field Assistant	50	20
Chemistry Technician	30	25
Draftsman/Cartographer	10	0

Table 4-9.

Field Equipment and Materials

Mapping

Topographic maps (1:24,000), color infra-red aerial photographs (1:60,000), mylar overlays for photographs with provisional and classification boundaries, map unit releve forms, plant collection bags, plant tags, local flora, plant press, acetate pens, pencil and notebook.

Permanent Plots

Transit and stadia rods, 50 m steel tapes, PVC pipe or steel re-bar stakes, metal plot tags, engraving tool, 35 mm camera, color film, diameter tape, releve forms, plant collection bags, plant tags, plant press, pencil and notebook.

Lichen Plots

Hammer and star-rock drill, 20X25 cm quadrat frame, 35 mm camera, color film, stainless steel plot tags, engraving tool, collecting bags, species check list forms.

Evergreen Plants

Notebook and pencil, stainless steel plant tags, engraving tool, plant pathology comparison charts, 30 cm rule graduated in mm, notebook and pencil, collecting bags.

Trees

Teflon coated increment corer (16"), solvent and distilled water in squirt bottle, plastic drinking straws, carrying case for wood cores, metal tree tags, engraving tool, 35 mm camera, film, pencil and notebook.

Mapping of each basin will require about 0.25 man days of air photo interpretation, 4 man days of field effort. Final plant determinations and drafting should be done in the laboratory.

Large plot location and description. In each landscape unit, large 50 X 50 permanent plots should be located and established. These should contain good stands of fruticose and foliose lichens, evergreen plants (both shrubs and trees), and mature forest trees. In each unit a minimum of five plots should be set up to provide access to the required taxa. All taxa might be contained in a single plot. Plots should be staked, tagged, located precisely on the geobotanical maps, and reference sightings made to prominent terrain features. A series of oblique photographs to record general aspect and vegetation should be taken of each plot. Each plot should be described with the releve method which will provide a complete inventory of flora and estimates of individual species abundance. Cover values should be recorded for scrubs, herbs and ground layers. Trees should be recorded by species, number and dbh (diameter at breast height).

Set up and description of each plot should take about 0.25 of a man-day.

4.5.2.2 Attribute Sampling and Monitoring

Lichens. Ten small 20 X 25 cm microplots are set up in each of the 5 larger (50 X 50) macro-plots to record ground and rock lichen communities. The plots can be marked with small stainless steel stakes or small holes in rock surfaces using a star-rock drill and hammer. The basic method is that of Hale (1982). Vertical whole plot photographs and oblique aspect photographs are taken for each plot. A complete as possible listing of lichens is made. Voucher collections should be made outside of the microplots. A large handful (5-10 g) of each common fruticose or foliose lichen is collected from within each large plot for elemental analysis (see Table 4.1).

Setting up and recording 10 microplots in each macroplot and sampling for elemental content of lichens takes about 0.5 of a man day.

Evergreens. Within the macroplots available, evergreen species should be sampled. Evergreen shrubs or conifers are best; evergreen herbs are of dubious value. When possible, the same species should be used throughout a wilderness area. Ten individual plants should be tagged and their locations recorded in a macroplot. Ten individual branches should also be tagged on each plant to allow for replication and future repeated measurements. Photographs of each individual plant should be taken.

Using standard color charts and photographs of leaf damage from known pollution effects, each branch is examined and scored for signs of necrosis (flecking, tip-die-back, etc.) and

chlorosis. Further literature and method development is needed here. A good start is Miller and McBride (1975).

Samples of leaves of each age class (about 20 grams fresh weight) should be taken from neighboring unmarked plants. Dead and living leaves should be collected separately. Five samples per macroplot are recommended.

A record should be made of leaf numbers per age class for each marked branch.

Trees. Methods of tree coring and wood elemental analysis are well worked out by Berisch and Ragsdale (1985). Within the five macroplots, ten trees of each dominant species should each be cored three times at breast height. Two of the three cores are used for elemental analysis in five-year increments and the remaining core is used for growth analysis. In subsequent years, only short cores will be necessary. Each tree should be photographed, tagged, and its location recorded. Coring of 20 trees takes about 0.5 of a man day.

4.6 References

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